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Substrates and controlled-release fertilizations on the quality of eucalyptus cuttings

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ABSTRACT
To produce cuttings with quality, the most appropriate nutritional management strategies should be sought to reduce wastage of fertilizer, while accounting for the characteristics of each substrate. This study evaluated the effect of substrates and doses of controlled-release fertilizer on the quality of *Eucalyptus grandis* Hill ex Maiden x *Eucalyptus urophylla* S. T. Blake cuttings. The substrates consisted of several mixtures: vermiculite+carbonized rice chaff+coconut fibre (1:1:1); vermiculite+coconut fibre (1:1); and vermiculite+carbonized rice chaff (1:1). These mixtures were added to 2, 4, 6 and 8 kg of controlled-release fertilizer per cubic meter of substrate. The substrates that do not support root development and have lower water retention, independently of the dose of controlled-release fertilizer, reduce the quality of the root system. For substrates with proper values of water retention, such as vermiculite+coconut fibre (1:1) and vermiculite+carbonised rice chaff+coconut fibre (1:1:1), the utilization of dose 2 kg of controlled-release fertilizer to each cubic meter is enough to promote cuttings with greater quality of the root systems and proper heights and stem diameters.

Palavras-chave:
nutrientes
fertilizante
sistema radicular
retenção de água
viveiro florestal

Substratos e fertilizações de liberação controlada na qualidade de mudas clonais de eucalipto

RESUMO
Deve-se buscar, para produzir mudas de qualidade, manejos nutricionais mais adequados que reduzam o desperdício de fertilizantes considerando as características de cada substrato. Este estudo avaliou o efeito de substratos e doses de fertilizante de liberação controlada na qualidade de mudas clonais de *Eucalyptus grandis* Hill ex Maiden x *Eucalyptus urophylla* S. T. Blake. Os substratos se constituíram das seguintes misturas: vermiculita+casca de arroz carbonizada+fibra de coco (1:1:1); vermiculita+fibra de coco (1:1) e vermiculita+casca de arroz carbonizada (1:1). A essas misturas foram adicionados 2, 4, 6 e 8 kg de fertilizante de liberação controlada por metro cúbico do substrato. Os substratos que não dão suporte ao crescimento das raízes e possuem baixa retenção de água, independente da dose de fertilizante de liberação controlada, reduzem a qualidade do sistema radicular. Para substratos com capacidade adequada de retenção de água, como os constituídos por vermiculita+fibra de coco (1:1) e vermiculita+casca de arroz carbonizada+fibra de coco (1:1:1) a dose 2 kg de fertilizante de liberação controlada por metro cúbico é suficiente para formar mudas com alturas da parte aérea e diâmetros do colo adequados e sistema radicular de qualidade.

Introduction

The area occupied by *Eucalyptus* forests in Brazil totalled 4,873.851 ha in 2011 (ABRAF, 2012). The establishment of uniform and highly productive stands is ensured predominantly by the production of *Eucalyptus* clones, which ensures the full maintenance of the characteristics of the mother tree. For proper establishment of clones in the field, it should be an operational program, defining areas of planting, silvicultural techniques to be adopted, the process of cutting production and the implementation and management of clonal forests (Alfenas et al., 2009).

Currently, mini-cutting is the most common method used by Brazilian forestry companies to clone *Eucalyptus* (Almeida et al., 2007). In this method, shoots from plants propagated by conventional cutting are used as source of propagules. In a schematic sequence of this method, initially, it is pruning the top of the budding of rooted cutting, and after the emission of budding from axillary sprouts mini-cuttings are collected (Alfenas et al., 2009).

In this production system, the main factors that affect the development and quality of cuttings are the genetic materials, water levels, nutrition, type of container and substrates (Silva et al., 2012).

An ideal substrate meets the physical and chemical requirements of the plant and contains a sufficient quantity of essential elements (air, water and nutrients) for plant growth

(Silva et al., 2010). The physical properties of substrates are most important because the air-water relationship can not be altered during cultivation (Verdonck et al., 1983).

Different mineral and organic sources may be used, i.e., either pure or mixed, for plant substrate, and coconut fibre, carbonized rice chaff and vermiculite have a high potential for use in the production of *Eucalyptus urophylla* x *E. grandis* cuttings (Silva et al., 2012). The use of alternative substrates requires knowledge of new characteristics for mixing and also for offering best conditions to plant growth during the crop (Şirin et al., 2010).

The fertilization method of incorporating the fertilizer into the substrate prior to sowing or staking may be used to supply nutrients in forest nurseries. One way to increase the efficiency is to use sources that provide for a more controlled-release of nutrients that results in certain benefits, such as reductions in the manual labour necessary for side-dressing fertilization, the burning of leaves from fertilizers that are applied to the surface, the loss of nitrogen via the volatilisation of ammonia, the loss of nutrients through leaching and the harmful effects of salinity of the substrate on cuttings (Sharma, 1979).

To produce cuttings with quality, the most appropriate nutritional management strategies should be sought to reduce wastage of fertilizer, while accounting for the characteristics of each substrate. Thus, the goal of this study was to determine the effect of substrates and doses of controlled-release fertilizer on the quality of *Eucalyptus grandis* Hill ex Maiden x *Eucalyptus urophylla* S. T. Blake cuttings.

Material and Methods

The experiment was conducted from Dec. 2009 to Feb. 2010 in a suspended and sectorised nursery at Botucatu, São Paulo State, Brazil (22º 51' S; 48º 25' W). The climate of the region is Cwa according to the Köppen classification.

The *E. urophylla* x *E. grandis* mini-cuttings were obtained from the first collection of mini-clonal hedge that was grown in a semi-hydroponic system of "canaletão" (gutters) with medium-grain sand. For each mini-cutting, a pair of leaves was maintained with a 50% reduction of the total leaf area. Each mini-cutting was 7 cm (± 1 cm) in total length. The mini-cuttings were planted in plastic tubes (50 cm^3) with 2 cm of the basal region inserted into the substrate.

The raw materials (fine vermiculite, carbonized rice chaff and coconut fibre) were combined to form three substrates: vermiculite+carbonized rice chaff+coconut fibre (V + CR C + CF 1:1:1, v:v), vermiculite+coconut fibre (V + CF 1:1, v:v) and vermiculite+carbonized rice chaff (V + CRC 1:1, v:v). The choice of these substrates was based on the conclusions of Silva et al. (2012) and also because they are commonly used in Brazilian forest nurseries.

Four doses (2, 4, 6 and 8 kg m^{-3}) of controlled-release fertilizer, with an N-P-K formula of 19-6-10 and a biodegradable resin coating that was capable of releasing 16% N, 5% P_2O_5 and 8% K_2O, were applied to each substrate. The total N consisted of 9% ammonium-nitrogen and 10% nitrate-nitrogen. The fertilizer formulation was derived from ammonium nitrate, ammonium phosphate, calcium phosphate and potassium sulphate, and the time period for the total release of nutrients was 90 to 120 days.

Following the preparation of the substrate, the polypropylene trays with 176 cells containing the plastic tubes with the mini-cuttings were transferred to an automated greenhouse with controlled temperature (less than or equal to 30 °C) and relative humidity (greater than 80%, maintained through nebulisation).

The mini-cuttings remained in this environment for 30 days for rooting and were subsequently transferred to a shade house (with 50% light reduction) to acclimatise for 20 days. Subsequently, they were transferred to a sunlit area for 40 days to grow and harden. In this last stage, the plants were covered with transparent plastic and irrigated with water level 12 mm in three times per day by microsprinklers.

The side-dressing fertilization during the growing phase was completed twice per week using the following formulation: ammonium sulphate, potassium nitrate, calcium nitrate and monoammonium phosphate, purified at concentrations of 520, 140, 360, 340 and 169 mg L^{-1} of N, P, K, Ca and S respectively. During the hardening stage, the fertilization was only performed using potash at a concentration of 300 mg L^{-1} of K.

For the physical analysis of the substrates, the following characteristics were determined according to the method described by Guerrini & Trigueiro (2004): total porosity, macroporosity, microporosity and water retention.

To evaluate the quality of the cuttings, the following morphological parameters were measured 90 days after the mini-cuttings were brought into the greenhouse: height (cm), measured using a millimetre ruler, from the base of the stem to the apical bud; stem diameter (mm) measured using a precision calliper; shoot, root and total dry weights (g) of the segment of the cuttings that was closest to the substrate. To determine the root dry weight, the roots were washed on a sieve using tap water. Subsequently, the roots and shoots were dried to a constant weight in an oven at 70 °C and then weighed with a high-precision electronic scale.

In addition to the morphological parameters, the quality of the root system of the cuttings was also evaluated. This parameter had four categories: "optimum" indicated a well-structured root system with no flexibility and the presence of new roots; "good" was assigned to root systems that had good structure but some flexibility, which would require greater care in planting to avoid harming the field performance; and "poor" was assigned to root systems that had no aggregated substrate or new roots and was considered unfit for planting in the field. Both "optimum" and "good" root systems were considered "able" for planting.

The experiment was conducted using a completely randomised design with a factorial scheme that consisted of three substrates and four doses of controlled-release fertilizer with four replications of 43 cuttings. This approach is considered useful for evaluating the ten central cuttings per replication. An analysis of variance was performed. The qualitative data were compared using the Tukey test at a 5% probability, and the quantitative data were analysed with a regression analysis that used the biological significance, the significance of the estimators of the parameters that were determined by the F test, up to 5%, and the highest coefficient of determination as the selection criteria for the regression models.

Results and Discussion

All substrates had porosities within the appropriate range of total porosity values (75-85%), as proposed by Gonçalves & Poggiani (1996). Moreover, no substrates simultaneously met the appropriate macropososity (35-45%) and microporosity (45-55%) values that were suggested by these authors. The water retention of the substrate V + CRC (1:1) was below the appropriate range (20-30 mL of water by plastic tube) reported by Gonçalves & Poggiani (1996) (Table 1).

Table 1. Physical properties of substrates used in the experiment

Substrates	Porosity (%)			Water retention
	Macro	Micro	Total	(mL by plastic tube)
V + CR C + CF (1:1:1)	28.06 c	51.76 a	79.82 a	26.30 a
V + CF (1:1)	38.60 b	39.34 b	77.94 b	20.65 b
V + CRC (1:1)	42.24 a	35.08 c	77.32 b	19.31 c
CV (%)	5.31	2.20	2.25	2.60

Means followed by the same letter in the column are not significantly different according to the Tukey test ($p < 0.05$); V - Vermiculite; CRC - Carbonised rice chaff; CF - Coconut fibre; proportions based on the volume ratio (v:v)

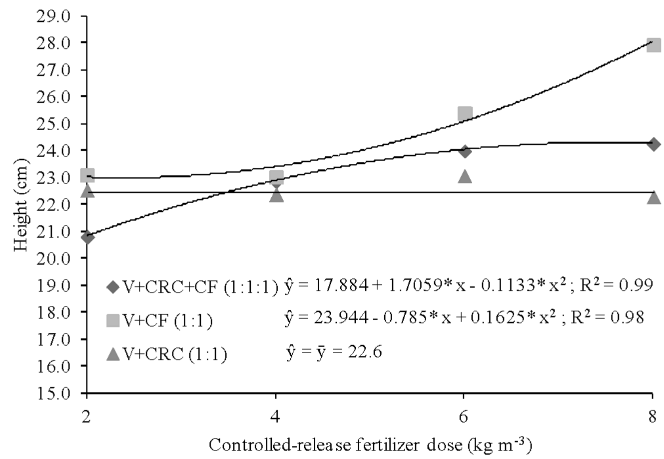
Silva et al. (2013) asserted that substrates with higher water retention resulted in higher development of various morphological parameters of the *Eucalyptus urophylla* x *E. grandis* seedlings with lower controlled-release fertilizer doses.

There was a pronounced effect of the substrate and controlled-release fertilizer dose on all of the morphological parameters, indicating a dependency between the effects of these factors. Nutrition is recognized as a primary limiting factor affecting growth and vigor of seedlings and juvenile trees in plantations (Smethurst, 2010) and there has been increased reliance on seedling fertilization as a silvicultural technique to improve plant quality or promote early plantation growth (Salifu et al., 2009).

Increases of the fertilizer dose in substrates V + CF (1:1) and V + CRC + CF (1:1:1) resulted in increases in the height of the cuttings, whose maximum heights were 28.1 and 24.3 cm at 8.0 and 7.5 kg m^{-3}, respectively. Moreover, no influence of the dose was observed for the substrate V + CRC (1:1), whose mean height was 22.6 cm (Figure 1).

Despite these findings, all of the substrates at a dose of 2 kg m^{-3} produced cuttings with heights that were within the quality standard, which ranges from 20 to 35 cm, as established by Gomes et al. (2003). This dose is lower than that found by Moraes Neto et al. (2003), that produced *Guazuma ulmifolia*, *Croton floribundus*, *Peltophorum dubium*, *Gallesia integrifolia* and *Myroxylon peruiferum* seedlings with good quality at a doses 3.2 and 4.8 kg m^{-3} of controlled-release fertilizer.

Unlike Gomes et al. (2002), who suggested the adoption of height alone to estimate the quality of cuttings, Fonseca



*Significant at $p < 0.05$ according to the F test

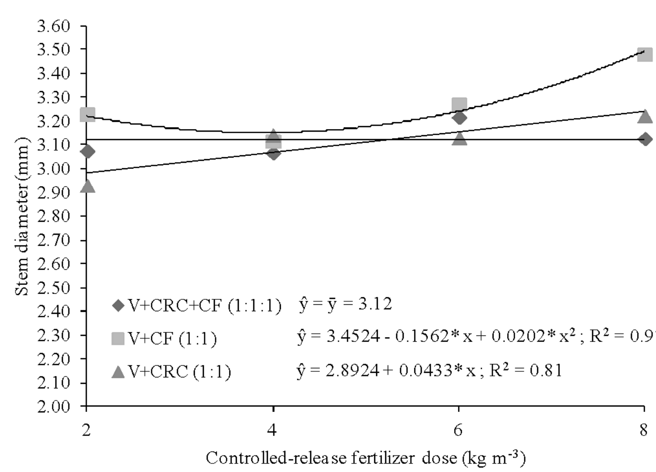
Figure 1. Height of *E. urophylla* x *E. grandis* cuttings, as affected by the controlled-release fertilizer doses and substrates: vermiculite (V), carbonised rice chaff (CRC) and coconut fibre (CF)

et al. (2002) asserted that morphological parameters and the relationships used to evaluate the quality of the cuttings should not be used alone to avoid the risk of selecting higher, weaker cuttings and discarding the smaller, stronger cuttings.

Increases in the fertilzer doses of the substrates V + CF (1:1) and V + CRC (1:1) led to increases in the stem diameter with values of 3.50 and 3.24 mm, respectively, at the highest dose. Moreover, no influence of the dose was observed for substrate V + CRC + CF (1:1:1), in which the stem diameter was 3.12 mm (Figure 2).

Despite these results, all substrates at the lowest fertilizer dose produced cuttings with stem diameters that were greater than the minimum value of 2.5 mm established by Lopes et al. (2007).

The shoot dry weights of 1.14 g under the dose of 2 kg m^{-3} and 1.81 g in dose of 8 kg m^{-3} were estimated for the substrate V + CF (1:1). This difference corresponds to a weight increase



*Significant at $p < 0.05$ according to the F test

Figure 2. Stem diameter of *E. urophylla* x *E. grandis* cuttings for various controlled-release fertilizer doses and substrates: vermiculite (V), carbonised rice chaff (CRC) and coconut fibre (CF)

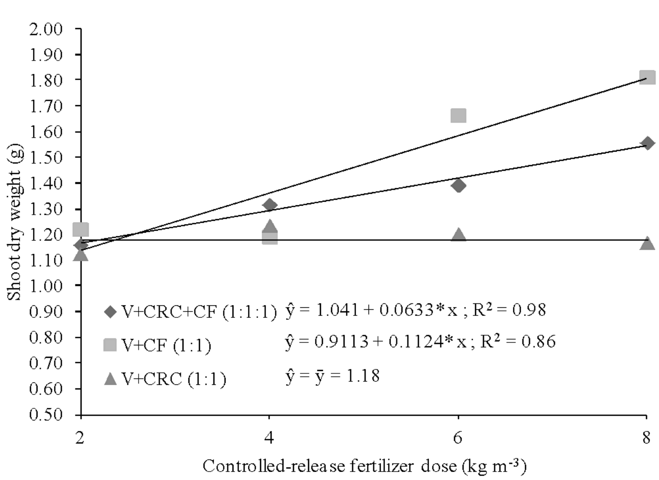
of 59%. For the substrate V + CRC + CF (1:1:1), the shoot dry weights were 1.17 g in the dose of 2 kg m^{-3} and 1.55 g under the dose of 8 kg m^{-3}, which corresponds to a difference of 33%. For substrate V + CRC (1:1), an increase in the fertilizer dose did not influence the shoot dry weight, which was 1.18 g (Figure 3).

The shoot dry weight is related to the quality and quantity of leaves. This feature is very important because the leaves are a major source of photoassimilates (e.g., sugars, amino acids and hormones) and nutrients. These products help the plant adapt to changes after planting that require a good supply of photoassimilates, which must be supplied to the roots during the first month after planting (Gonçalves & Benedetti, 2000).

Higher doses in the substrate V + CF (1:1) led to a linear increase in the root dry weight ($\hat{y} = 0.4201 + 0.0233^* x$; $R^2 = 0.55$), yielding 0.47 g in the dose of 2 kg m^{-3} and 0.61 g under the dose of 8 kg m^{-3}, which is equivalent to a difference of 30%. Moreover, for the substrate V + CRC + CF (1:1:1), this effect was not observed, and the root dry weight was 0.48 g. For the substrate V + CRC (1:1), increasing the dose of fertilizer decreased the root dry weight ($\hat{y} = 0.4945 - 0.0091^* x$; $R^2 = 0.58$). This undesirable reduction can cause drought stress because the roots do not absorb sufficient quantities of water to balance the loss from transpiration (Gonçalves & Benedetti, 2000).

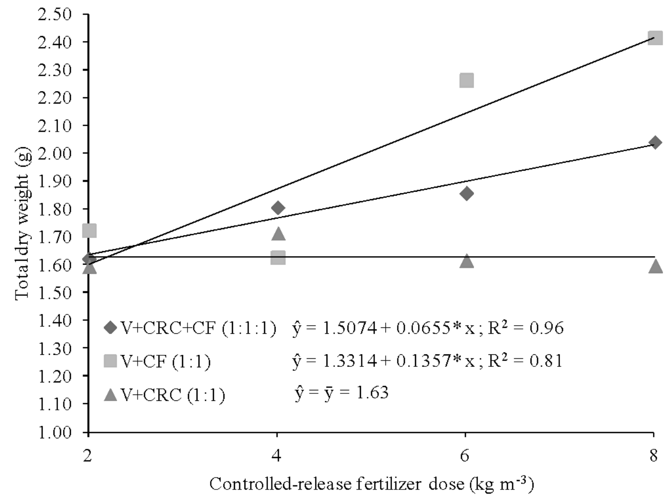
Increases in the fertilizer doses in the substrates V + CF (1:1) and V + CRC + CF (1:1:1) corresponded to increases in the total dry weight with values of 2.42 and 2.03 g, respectively, at the highest dose. In contrast, no effect was observed for substrate V + CRC (1:1), which corresponded to total dry weight of 1.63 g (Figure 4).

The total dry weight and stem diameter correlate with survival and the initial development of cuttings after planting (Thompson, 1985). Furthermore, the use of controlled-release nutrient sources enables a greater production of total dry weight and higher nutrient contents in the shoots of cuttings compared to formulations with equal amounts of N, P and soluble and rapid-release K (Quiqui et al., 2004).



*Significant at $p < 0.05$ according to the F test

Figure 3. Shoot dry weight of *E. urophylla* x *E. grandis* cuttings for various controlled-release fertilizer doses and substrates: vermiculite (V), carbonised rice chaff (CRC) and coconut fibre (CF)



*Significant at $p < 0.05$ according to the F test

Figure 4. Total dry weight of *E. urophylla* x *E. grandis* cuttings for various controlled-release fertilizer doses and substrates: vermiculite (V), carbonised rice chaff (CRC) and coconut fibre (CF)

The growth in substrate V + CF (1:1) responded to increasing fertilizer doses for all morphological parameters and was superior to the substrates V + CRC + CF (1:1:1) and V + CRC (1:1) in height and stem diameter at all doses. Substrates should be sufficiently porous to allow for good aeration for mini-cuttings because oxygen is essential for root respiration and substrates should also retain sufficient water for the initial development of the cutting and to enable survival in the field for a given period of time (Xavier et al., 2009).

Although all treatments resulted in the appropriate development of the height and stem diameter, not all treatments produced cuttings with high-quality root systems. The development of root system can be influenced by fertilization (Jacobs et al., 2004), irrigation (Bayley & Kietzka, 1997) substrate and its physical properties (Arnold & Struve, 1993) and size, shape and spacing of the containers (Aphalo & Rikala, 2003).

The substrates and controlled-release fertilizer doses differed ($p < 0.05$) with respect to the number of poor, good and able root systems that they produced. However, only the substrate had an influence on optimum root systems (Table 2).

The substrates V + CRC + CF (1:1:1) and V + CF (1:1), independent of dose, produced a greater number of cuttings with optimum, good and able root systems. The substrate V + CRC (1:1) resulted in a greater number of root systems that were structureless and without new roots, which negatively affected the morphological development. The fact that the substrate does not support root development, limits the growth of the roots and affects the quality (Silva et al., 2012), survival and development of the cuttings after planting in the field (Maeda et al., 2006). Furthermore, the lower water retention of substrate V + CRC (1:1) may have contributed to the lower root system quality because, according Huett & Morris (1999), the loss of nutrients through leaching increases proportionally with the volume of substrate and lower water retention and cation exchange capacity. If the root systems of the cuttings are not of high quality, water and

Table 2. Quality of the root system of *Eucalyptus grandis x Eucalyptus urophylla* as affected by the controlled-release fertilizer doses and substrates

Substrates	Controlled-release fertilizer dose (kg m^{-3})				Means
	2	4	6	8	
			Poor (%)		
V + CRC + CF (1:1:1)	7.5 Ba	0 Ba	2.5 Ba	7.5 Ba	4.4
V + CF (1:1)	0 Ba	0 Ba	0 Ba	0 Ba	0
V + CRC (1:1)	60 Aab	65 Aab	55 Ab	85 Aa	66.3
Means	22.5	21.7	19.2	30.8	
			Good (%)		
V+CRC+CF (1:1:1)	77.5 Aa	70 Aa	82.5 Aa	80 Aa	77.5
V+CF (1:1)	75 Aa	67.5 Aa	75 Aa	85 Aa	75.6
V+CRC (1:1)	40 Bab	35 Bab	45 Ba	15 Bb	33.8
Means	64.2	57.5	67.5	60	
			Optimum (%)		
V+CRC+CF (1:1:1)	15	30	15	12.5	18.1 A
V+CF (1:1)	25	32.5	25	15	24.4 A
V+CRC (1:1)	0	0	0	0	0 B
Means	13.3	20.8	13.3	9.2	
			Able (%)		
V + CRC + CF (1:1:1)	92.5 Aa	100 Aa	97.5 Aa	92.5 Aa	95.6
V + CF (1:1)	100 Aa	100 Aa	100 Aa	100 Aa	100
V + CRC (1:1)	40 Bab	35 Bab	45 Ba	15 Bb	33.8
Means	77.5	78.3	80.8	69.2	

Means followed by the same capital letter in the same category in the column and the same lowercase letter across the row are not significantly different according to the Tukey test ($p < 0.05$)

V - Vermiculite; CRC - Carbonised rice chaff; CF - Coconut fibre; proportions are based on the volume ratio (v:v)

nutrients are not absorbed in sufficient quantities to meet the needs of the plant, resulting in the typical symptoms of reduced growth due to water or nutrient deficiencies. Usually, in times of drought, these plants die as a result of the spiralling and throttling in the roots (Alfenas et al., 2009).

Although the substrates V + CRC + CF (1:1:1) and V + CF (1:1) had different physical characteristics in their macro and microporosities, they corresponded to the best quality results in their root systems. Other values for the physical characteristics of the substrates, in addition to those mentioned in the literature, can also be considered suitable depending on the species, type of container, propagation forms, water levels, nutrition and materials used in the substrates (Silva et al., 2012). Furthermore more research is needed to address fertility issues with substrates before it can be recommended (Şirin et al., 2010) and efforts should be directed toward the use of substrates that enable further development of the cuttings in a shorter period of time to reduce costs (Simões et al., 2012).

Conclusions

1. Although the substrate vermiculite+carbonised rice chaff (1:1) at a dose 2 kg of controlled-release fertilizer to each cubic meter of this substrate produces cuttings with proper heights and stem diameters, it does not produce adequate numbers of good, optimum and able root systems for planting in the field.

2. The substrates that does not support root development and have lower water retention, independently of the dose of controlled-release fertilizer, reduce the quality of the root system.

3. For substrates with proper values of water retention, such as vermiculite+coconut fibre (1:1) and vermiculite+carbonised rice chaff+coconut fibre (1:1:1), the utilization of dose 2 kg of controlled-release fertilizer to each cubic meter is enough to promote cuttings with greater quality of the root systems, proper heights and stem diameters and reduce wastage of fertilizer.

Literature Cited

ABRAF - Associação Brasileira de Produtores de Florestas Plantadas. 2012. <http://www.abraflor.org.br/estatisticas/abraf12/abraf12-br.pdf>. 5 Aug. 2012.

Alfenas, A. C.; Zauza, E. A. V.; Mafia, R. G.; Assis, T. F. Clonagem do Eucalipto. In: Alfenas, A. C.; Zauza, E. A. V.; Mafia, R. G.; Assis, T. F. Clonagem e doenças do Eucalipto. Viçosa: UFV, 2009. p.21-121.

Almeida, F. D.; Xavier, A.; Dias, J. M. M.; Paiva, H. N. Auxin (IBA and NAA) effects on minicuttings rooting of *Eucalyptus cloeziana* F. Muell. Revista Árvore, v.31, p.455-463, 2007.

Aphalo, P.; Rikala, R. Field performance of silver-birch planting-stock grown at different spacing and in containers of different volume. New Forests, v.25, p.93-108, 2003.

Arnold, M. A.; Struve, D. K. Root distribution and mineral uptake of coarse-rooted trees grown in cupric hydroxide-treated containers. HortScience, v.28, p.988-992, 1993.

Bayley, A. D.; Kietzka, J. W. Stock quality and field performance of *Pinus patula* seedlings produced under two nursery growing regimes during seven different nursery production periods. New Forests, v.13, p.341-356, 1997.

Fonseca, É. P.; Valéri, S. V.; Miglioranza, É.; Fonseca, N. A. N.; Couto, L. Target seedlings of *Trema micrantha* (L.) Blume grown under different periods of shading. Revista Árvore, v.26, p.515-523, 2002.

Gomes, J. M.; Couto, L.; Leite, H. G.; Xavier, A.; Garcia, S. L. R. Morphological parameters quality for the evalution of *Eucalyptus grandis* seedling. Revista Árvore, v.26, p.655-664, 2002.

Gomes, J. M.; Couto, L.; Leite, H. G.; Xavier, A.; Garcia, S. L. R. Growth of *Eucalyptus grandis* seedlings produced in different sized tubes and N-P-K fertilization. Revista Árvore, v.27, p.113-127, 2003.

Gonçalves, J. L. M.; Benedetti, V. Produção de mudas de espécies nativas: substrato, nutrição, sombreamento e fertilização. In: Gonçalves, J. L. M.; Benedetti, V. Nutrição e fertilização florestal. Piracicaba: IPEF, 2000. p.309-350.

Gonçalves, J. L. M.; Poggiani, F. Substrates for seedling production. In: Congresso Latino Americano de Ciência do Solo, 13, 1996, Águas de Lindóia. Proceedings… Águas de Lindóia: USP ESALQ/SBCS/CEA/SLACS/SBM, 1996. CD-Rom

Guerrini, I. A.; Trigueiro, R. M. Physical and chemical attributes of substrates composed of biosolids and carbonized rice chaff. Revista Brasileira de Ciência do Solo, v.28, p.1069-1076, 2004.

Huett, D. O.; Morris, S. C. Fertilizer use efficiency by containerised nursery plants. 3. Effect of heavy leaching and damaged fertilizer prills on plant growth, nutrient uptake, and nutrient loss. Australian Journal of Agricultural Research, v.50, p.217-222, 1999.

Jacobs, D. F.; Rose, R.; Haase, D. L.; Alzugaray, P. O. Fertilization at planting inhibits root system development and drought avoidance of Douglas-fir (*Pseudotsuga menziesii*) seedlings. Annals of Forest Science, v.61, p.643-652, 2004.

Lopes, J. L. W.; Guerrini, I. A.; Saad, J. C. C. Quality of eucalyptus seedlings under different depths of irrigation and two substrates. Revista Árvore, v.31, p.835-843, 2007.

Maeda, S.; Andrade, G. C.; Ferreira, C. A.; Silva, H. D.; Agostini, R. B. Alternative substrates for the production of *Eucalyptus badjensis* seedlings obtained from residue of waste and brewing industry and goat. Comunicado Técnico Embrapa Florestas, v.157, p.1-5, 2006.

Moraes Neto, S. P.; Gonçalves, J. L. M.; Rodrigues, C. J.; Geres, W. L. A.; Ducatti, F; Aguirre Junior, J. H. Production of seedlings of native tree species combined with controlled-release and soluble ready fertilizers. Revista Árvore, v.27, p.779-789, 2003.

Quiqui, E. M. D.; Martins, S. S.; Pintro, J. C.; Andrade, P. J. P.; Muniz, A. S. Growth and mineral composition of eucalyptus seedlings cultivated under conditions of different sources of fertilizers. Acta Scientiarum Agronomy, v.26, p.293-299, 2004.

Salifu, K. F.; Jacobs, D. F.; Birge, Z. K. D. Nursery nitrogen loading improves field performance of bareroot oak seedlings planted on abandoned mine lands. Restoration Ecology, v.17, p.339-349, 2009.

Sharma, G. C. Controlled-release fertilizers and horticultural applications. Scientia Horticulturae, v.11, p.107-129, 1979.

Silva, J. I.; Vieira, H. D.; Viana, A. P.; Barroso, D. G. Development of *Coffea canephora* Pierre ex A. Froehner transplants cultivated in different substrates and containers. Coffee Science, v.5, p.38-48, 2010

Silva, R. B. G.; Simões, D.; Andrade, F. R.; Silva, M. R. Quality of *Eucalyptus* seedlings as a function of substrates and controlled-release fertilization. Revista Interciência, v.38, p.215-220, 2013.

Silva, R. B. G.; Simões, D.; Silva, M. R. Quality of *Eucalyptus urophylla* x *E. grandis* cuttings as a function of substrate. Revista Brasileira de Engenharia Agrícola e Ambiental, v.16, p.297-302, 2012.

Simões, D.; Silva, R. B. G.; Silva, M. R. Composition of the substrate on the development, quality and cost of production of seedlings of *Eucalyptus grandis* Hill ex Maiden x *Eucalyptus urophylla* S. T. Blake. Ciência Florestal, v.22, p.91-100, 2012.

Şirin, U.; Ertan, E.; Ertan, B. Growth substrates and fig nursery tree production. Scientia Agricola, v.67, p.633-638, 2010.

Smethurst, P. J. Forest fertilization: trends in knowledge and practice compared to agriculture. Plant and Soil, v.335, p.83-100, 2010.

Thompson, B. E. Seedling morphological evaluation: what you can tell by looking. In: Evaluating seedling quality: Principles, procedures, and predictive of major tests workshop, 1, 1984, Corvallis. Proceedings… Corvallis: Forest Research Laboratory of Oregon State University, 1985. p.59-71.

Verdonck, O; Vleeschauwer, D.; Penninck, R. Barckcompost: a new accepted growing medium for plants. Acta Horticulturae, v.133, p.221-226, 1983.

Xavier, A.; Wendling, I.; Silva, R. L. Silvicultura clonal: princípios e técnicas. 1.ed. Viçosa: UFV, 2009. 272p.