

## Correlations between Eucalyptus Clonal Cutting Quality and Performance after Planting

Fábio Afonso Mazzei Moura de Assis Figueiredo<sup>1</sup> ,  
José Geraldo Araújo Carneiro<sup>2</sup>, Ricardo Miguel Penchel<sup>3</sup>,  
José Tarcísio Lima Thiebaut<sup>2</sup>, Jupiter Israel Muro Abad<sup>4</sup> ,  
Deborah Guerra Barroso<sup>2</sup> , Tiago Massi Ferraz<sup>1</sup> 

<sup>1</sup>Universidade Estadual do Maranhão (UEMA), São Luís, MA, Brasil

<sup>2</sup>Universidade Estadual do Norte Fluminense Darcy Ribeiro (UNF), Campos dos Goytacazes, RJ, Brasil

<sup>3</sup>Fibria Celulose S.A., Jacareí, SP, Brasil

<sup>4</sup>Toba Pulp Lestari (TPL), Porsea, Sumatra Utara, Indonesia

### ABSTRACT

This study assessed correlations of different characteristics of cuttings in the nursery of three hybrid clones of *Eucalyptus grandis* × *Eucalyptus urophylla* and growth in height after planting. The characteristic that presented greatest correlation with the initial growth was the canopy height and cutting height ratio. At 12 and 24 months in the field, the stem diameter was more important. The parameters assessed in the nursery that correlated positively with growth in the field at three and six months after planting were height, number of leaf pairs, number of root deformations and clod length. At 12 and 24 months the parameters that correlated negatively were diameter, number of leaf pairs and the number of root deformations. Despite presenting significant correlation, root deformations did not interfere in the initial growth of the plants under high rainfall conditions, but the effects became harmful over time resulting in a reduction in plant growth.

**Keywords:** quality score, silviculture, correlation between nursery and field.

### Correlações entre a Qualidade de Mudanças Clonais de Eucalipto e o Desempenho após o Plantio

### RESUMO

Este estudo avaliou as correlações de diferentes características de mudas, no viveiro, de três clones híbridos de *Eucalyptus grandis* × *Eucalyptus urophylla* e o crescimento em altura após o plantio. A característica que apresentou maior correlação com o crescimento inicial foi a relação entre o comprimento da copa e a altura da muda. Aos 12 e 24 meses no campo, o diâmetro do caule foi mais importante. Os parâmetros avaliados no viveiro que se correlacionaram positivamente com o crescimento no campo aos três e seis meses após o plantio foram altura, número de pares de folhas, número de deformações radiculares e comprimento de torrão. Aos 12 e 24 meses os parâmetros que se correlacionaram negativamente foram diâmetro, número de pares de folhas e número de deformações radiculares. Apesar de apresentar correlação significativa, as deformações das raízes não interferiram no crescimento inicial das plantas sob condições de alta pluviosidade, mas os efeitos se tornaram prejudiciais ao longo do tempo, resultando em uma redução no crescimento das plantas.

**Palavras-chave:** qualidade de mudas, silvicultura, correlação entre viveiro e campo.

## 1. INTRODUCTION AND OBJECTIVES

The production and use of good quality cuttings for commercial plantations is extremely important to obtain high productivity from *Eucalyptus* plantations (Assis, 2011, Freitas et al., 2009). According to Carneiro (1995), cutting quality is directly related to increased survival and initial growth of recently established plantations. Initial survival appears to be related to the interaction between plant quality (both morphological and physiological) and the field environment.

Research has endeavored to show the importance of cutting morphological characteristics to estimate the performance after planting (Fonseca, 2002). Morphological characteristics are the most used as attributes of cutting quality in forest nurseries and several studies have shown the importance of these characteristics in the performance of the plants in the field (Barroso et al., 2000; Figueiredo et al., 2011; Fonseca, 2002; Freitas et al., 2009). Cutting classification by nursery staff is of a more practical nature, but there is still no more correct definition in order to meet the demands for survival and development, taking into consideration the adversities found in the field (Gomes & Paiva, 2006).

Gomes et al. (2002) studied different morphological parameters of *Eucalyptus grandis* in 60-day old seedlings using clustering by Tocher. According to the authors, the height presented relative contribution of 50.26% and the H/D ratio 32.93% thus together presented a relative contribution of 83.19% to the cutting quality. However, at 90 days, the most relevant parameter for cutting quality was height, expressing a contribution of 31.42%.

Figueiredo et al. (2014) assessed the effect of root deformations and verified that *Eucalyptus* cuttings submitted to root deformations presented lower hydraulic conductivity in the root system and consequently fall in gas exchanges and reduction in photosynthetic system II maximum quantum yield.

Freitas et al. (2009) observed no difference in growth in height, diameter, canopy and root biomass in two *Eucalyptus grandis* × *Eucalyptus urophylla* clones until 14 months after planting, in function of the deformations and pruning in the cutting root systems. Correia et al. (2013) studied *Eucalyptus grandis* × *Eucalyptus urophylla*

and verified that the cutting age and recipient volume did not influence survival.

The objective of the present study was to verify the correlation of different characteristics of *Eucalyptus* clonal cuttings in the outplanting phase with growth in height after planting in the field.

## 2. MATERIALS AND METHODS

The experiment was carried out from July 2008 to July 2010 in an area from the company Fibria Celulose S.A., Aracruz, ES, Brazil, a municipality located at 40°11'29"W and 19°47'54"S, the soil is of the experimental area and is classified as dystrophic yellow argisol medium texture, clayey. The experiment consisted in two stages: cutting production for quality assessment; and planting, to assess field performance.

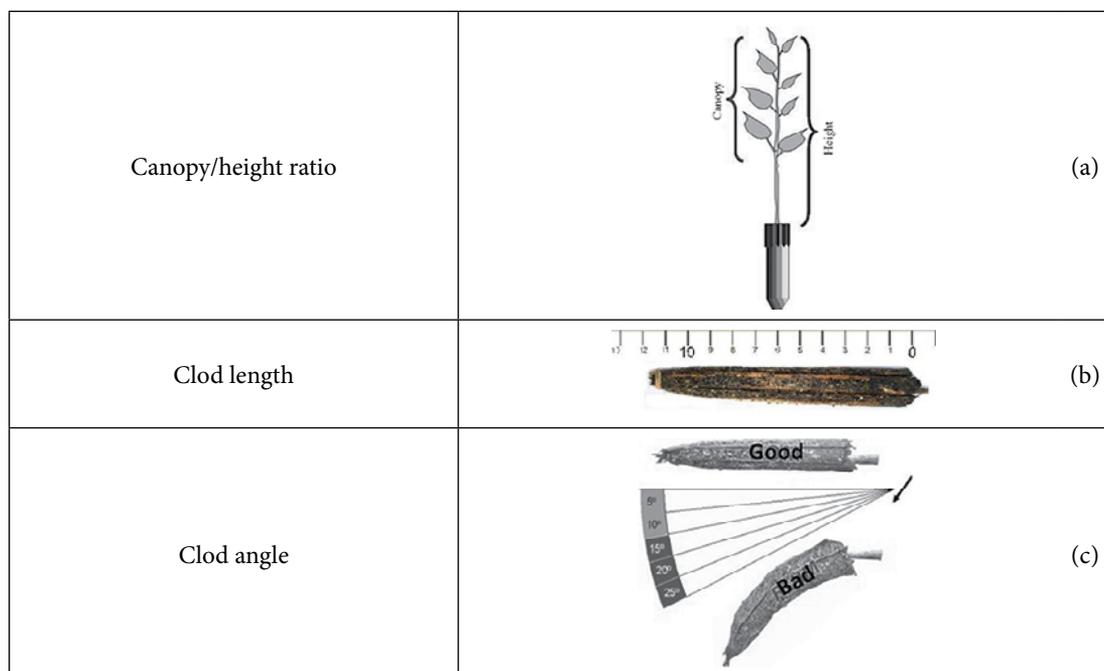
The cuttings were derived from three hybrid clones of *Eucalyptus grandis* × *Eucalyptus urophylla*, produced from the tip of mini rootstocks, ranging in length from 8 to 10 cm and approximately 2 mm diameter. The substrate used was a mixture consisting (v:v) of coconut fiber (Amafibra<sup>®</sup>) (30%), burnt and sieved rice husk (35%), medium vermiculite (35%), and fertilized with 2.0 kg.m<sup>-3</sup> osmocote<sup>®</sup> (19-06-10) and 2.0 kg.m<sup>-3</sup> simple superphosphate.

In the field, the cuttings were planted in single plots of 392 plants per clone, totalizing 1,176 plants in 3 × 3 m spacing, with basic fertilization of 100 grams 06-30-06 NPK formulation at planting per plant. At planting, a 500 ml dose per plots of pre-hydrated gel stockosorb micro<sup>®</sup> was used. Ninety days after planting, 150 grams 12-00-20 NPK + 0.7% of B was applied in the projection of the canopy of the plants.

The cuttings were assessed individually at outplanting age at around 100 days. The following parameters were assessed: height (H), stem diameter (D), stem height/diameter ratio (R-H/D), number of root deformations in the clod periphery (NRD) (strangling, spiraling and bending), number of leaf pairs (NLP), phytosanitary condition (PC) (evaluated by the presence or absence of diseases or leaf spots), chlorophyll index (CI) (evaluated by SPAD), clod length (CL), clod angle (CA) and the canopy/height ratio (R-C/H), according to methodology proposed by Penchel (2007) (Table 1). Figure 1 shows the assessment methodologies for the canopy/height ratio, clod length and clod angle characteristics.

**Table 1.** Description of morphological and physiological characteristics and phytosanitary conditions of rooted cuttings evaluated in the nursery immediately before planting in the field.

Parameter	Evaluation	Unit	Description
Height (H)	Quantitative	cm	Measuring the height of cuttings with millimetric ruler.
Stem diameter (D)	Quantitative	mm	Measuring stem diameter of cuttings with Caliper.
Number of leaf pairs (NLP)	Quantitative	number	Count the number of leaf pairs.
Number of root deformations (NRD)	Quantitative	number	Count the number of root deformations in the clod periphery.
Stem height/Diameter ratio (R-H/D)	Quantitative	number	Relationship between height and stem diameter.
Canopy/Height ratio (R-C/H)	Quantitative	number	Relationship between length of the canopy and height of the cuttings.
Chlorophyll index (CI)	Quantitative	number	Measurement with the portable chlorophyll meter of Opti-Science model - CCM 200.
Phytosanitary condition (PC)	Qualitative	grade	Grade 1 - cuttings showing symptoms of diseases, <i>Calonectria spp</i> , leaf spots and vascular diseases; Grade 3 - presence of leaf spots; Grade 5 - healthy cuttings.
Clod length (CL)	Qualitative	grade	Grade 1 - < 10 cm; Grade 2 - 10 cm to 10,9 cm; Grade 3 - 11 cm to 11,9 cm; Grade 4 - 12 cm to 12,9 cm Grade 5 - 13 cm.
Clod angle (CA)	Qualitative	grade	Grade 1 - > 10° degrees; Grade 2 - 8 to 10° degrees; Grade 3 - 4 to 7° degrees; Grade 4 - 1 to 2° degrees; Grade 5 - 0° degrees.



**Figure 1.** Methodology for evaluating the characteristics canopy height/shoot height (a), clod length (b) and clod angle (c).

Table 2 shows the means and standard deviation of parameters evaluated of rooted cuttings in the nursery immediately before planting in the field.

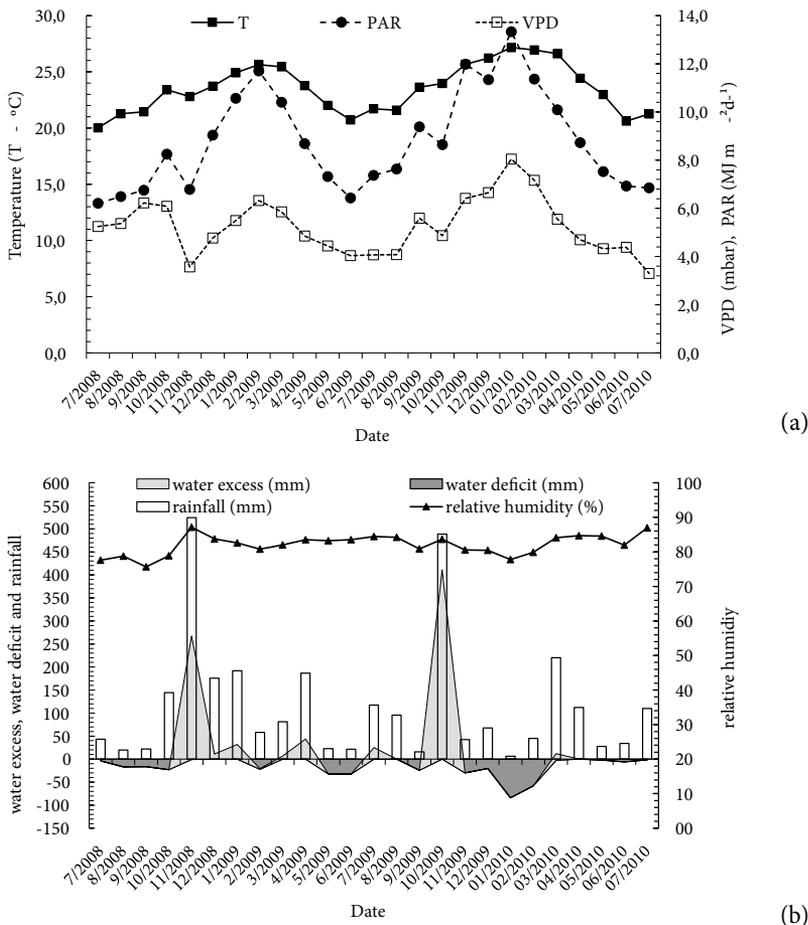
In the field, the cuttings were assessed for growth in height at three months, six months, one year and two years after planting. Figure 2 shows the climatological data of the experimental area during the 24 months of assessment after planting. The identification of the cuttings in the nursery was maintained in the field for measurement.

The data were analyzed using Pearson's correlation among nursery characteristics and Pearson's partial correlations between nursery characteristics and growth in height in the field. The correlations were tested using the t test at 5% level of probability. All these statistical analyses were performed using the SAEG version 9.0 software.

**Table 2.** Means and standard deviation of parameters evaluated of rooted cuttings evaluated in the nursery immediately before planting in the field.

Parameter	Average	Standard deviation
H	37.2	± 9.92
D	3.66	± 0.51
NLP	4.38	± 1.37
NRD	2.68	± 2.31
R-C/H	0.54	± 0.13
CI	11.70	± 5.07
R-H/D	10.20	± 2.55
PC	4.23	± 0.97
CL	3.09	± 0.70
CA	4.94	± 0.29

H: cutting height (cm); D: stem diameter (mm); NLP: number of leaf pairs; NRD: number of root deformation; R-C/H: canopy height and cutting height ratio (number); CI: chlorophyll index (number); R-H/D: cutting height and stem diameter ratio (number); PC: phytosanitary condition (grade); CL: clod length (grade); and CA: clod angle (grade). (n = 1,176)



**Figure 2.** Climatological data of the experimental area during the 24-month evaluation period after planting (July 2008 to July 2010). T: temperature; VPD<sub>air</sub>: vapor pressure deficit in the air; PAR: photosynthetically active radiation.

### 3. RESULTS AND DISCUSSION

Penchel's (2007) quality control, used in the present study, considers different observation parameters and direct measurements and their ratios. The analysis of correlation between these parameters (Table 3) indicated that the following were not significant: D and NRD; CL and NRD; CA and NRD; and CA and R-C/H; for the other characteristics the correlations were significant. The highest correlation observed was between R-H/D and H, of 0.85, that as a general rule, according to Cruz & Regazzi (1994), can indicate that there is a specific problem of collinearity between these parameters of the quality control system proposed by Penchel (2007). This was expected, since R-H/D is a function of H. Usually, in this case, the only one variable should be chosen. Despite this case, the other correlations were below 0.70 (absolute value) and did not indicate a problem of collinearity, by this practical rule.

The R-H/D and D correlation was negative (-0.08). In this sense, it was clear that it is preferable to use the simple variable of stem height and diameter as indicators of cutting quality, instead of a ratio between these variables. This statement is reinforced by Ataíde et al. (2010) who assessed *Eucalyptus* cutting density on trays and observed that the restrictions caused by the recipients induced smaller growth in stem diameter. Reis et al. (2008) assessed the spatial variation of *Eucalyptus grandis* cuttings and their relationship with

quality and found various combinations of height and stem diameter among the different treatments, but the relationship of these variables was not statistically different for part of the treatments.

Table 4 shows the height of eucalyptus plants at different periods after planting.

Pearson's partial correlation between the morphological and physiological characteristics of the eucalyptus clonal cuttings, assessed in the nursery, with their growth in height in the field at three and six months after planting, indicated positive correlations for H, NLP, NRD and CL (only at three months), and negative correlation for D (only at three months) and R-C/H (Table 5).

Cutting height is considered one of the oldest class characteristics for cutting classification and selection. The positive correlation between H and field height is in agreement with different studies such as that by Barroso et al. (2000), who assessed *Eucalyptus camaldulensis* and *E. urophylla* up to 10 months after planting, Freitas et al. (2008), who assessed the post-planting performance of eucalyptus clonal cuttings produced in different recipients and substrates up to 180 days after planting, and Figueiredo et al. (2011), who assessed the effect of biometric variations of eucalyptus clonal cuttings on field growth up to 12 months after planting. This correlation was attributed to a selection of the best cuttings in the nursery, with greater heights and consequently greater root development (Freitas et al.,

**Table 3.** Pearson's correlation matrix between morphological and physiological parameters of eucalyptus clonal cuttings evaluated in the nursery.

	H	D	NLP	NRD	R-C/H	CI	R-H/D	PC	CL	CA
H	1	-	-	-	-	-	-	-	-	-
D	0.43*	1	-	-	-	-	-	-	-	-
NLP	0.33*	0.37*	1	-	-	-	-	-	-	-
NRD	-0.20*	0.04 <sup>ns</sup>	-0.06*	1	-	-	-	-	-	-
R-C/H	0.41*	0.05*	-0.05*	-0.10*	1	-	-	-	-	-
CI	-0.64*	-0.33*	-0.32*	0.10*	-0.32*	1	-	-	-	-
R-H/D	0.85*	-0.08*	0.14*	-0.24*	0.44*	-0.53*	1	-	-	-
PC	0.48*	0.04*	0.20*	-0.32*	0.17*	-0.28*	0.50*	1	-	-
CL	0.41*	0.35*	0.24*	0.03 <sup>ns</sup>	0.06*	-0.29*	0.24*	0.19*	1	-
CA	0.19*	0.19*	0.05*	-0.0 <sup>ns</sup>	0.04 <sup>ns</sup>	-0.12*	0.11*	-0.06*	0.11*	1

H: cutting height; D: stem diameter; NLP: number of leaf pairs; NRD: number of root deformation; R-C/H : canopy height and cutting height ratio; CI: chlorophyll index; R-H/D : cutting height and stem diameter ratio; PC: phytosanitary condition; CL: clod length; and CA: clod angle.\*significant at 5% probability; <sup>ns</sup> not significant.

2005), that provides under favorable field conditions (mainly water in the soil), fast establishment and consequent growth in height.

The number of leaf pairs and clod length correlated positively with plant growth in the field. Inoue & Ribeiro (1988) studied photosynthesis and transpiration of *Eucalyptus grandis* and *E. saligna* clones and concluded that the capacity of the individual to produce and maintain a large leaf area influences different physiological characteristics and can interfere in post-planting performance. The results of these authors converge with those presented in Table 5, showing that outplanting cuttings with a larger leaf number may result in a greater initial growth of the plants.

The correlation observed between clod length and growth in the field shows the importance of the cuttings having a well-developed root system that adheres to the substrate, as emphasized by Carneiro (1995), Gomes & Paiva (2006) and Alfenas et al. (2009). This result also shows the importance of correctly filling the tubes with substrate and dimensioning and maintaining irrigation sprays, which can contribute to substrate loss.

The partial correlation between the stem diameter and plant height three months after planting presented an inverse negative ratio. This result was also reported by Figueiredo et al. (2011), who worked with eucalyptus clonal plants. The authors observed that cuttings

with thin stem diameter (less than 2 mm) presented equivalence in growth in height to three months after planting when compared to cuttings with medium (between 2.1 mm and 3 mm) and thick (3.1 mm and 4 mm) diameter cuttings. On the other hand, because the cuttings were produced in the same recipient, with a rigid wall and small volume (53 cm<sup>3</sup>), it is believed that a greater root volume may result also in greater occurrence of root deformations so that cuttings with larger diameters would present a greater number of root deformations.

An important point observed regarding root deformations is that they were significant but low magnitude (Table 5). In addition, this correlation increased in the assessment at 12 and 24 months in the field. Thus, the root deformations considered did not damage plant growth until six months after planting, which may be attributed to the low VPD<sub>air</sub> (Figure 2a) values and the high rainfall (Figure 2b) that may have

**Table 4.** Height (m) of eucalyptus plants in different periods after planting.

Period after planting	Average	Standard deviation
3 months	1.03	0.19
6 months	2.83	0.43
12 months	7.49	0.91
24 months	14.10	1.02

**Table 5.** Pearson partial correlation between morphological and physiological characteristics of eucalyptus clonal cuttings and growth in height, at three, six, 12 and 24 months after planting.

Parameter	Pearson partial correlation			
	3 months	6 months	12 months	24 months
H	0.00435*	0.00483*	0.01627*	0.02197*
D	- 0.05854*	NS	- 0.46335*	- 0.45612*
NLP	0.02219*	0.04379*	- 0.06425*	- 0.05650*
NRD	0.01047*	0.02588*	- 0.10132*	- 0.08487*
R-C/H	- 0.24405*	- 0.46507*	NS	NS
CI	NS	NS	NS	NS
R-H/D	NS	NS	NS	NS
PC	NS	NS	0.08868*	0.10708*
CL	0.03234*	NS	NS	NS
CA	NS	NS	NS	NS

H: cutting height; D: stem diameter; NLP: number of leaf pairs; NRD: number of root deformation; R-C/H: canopy height and cutting height ratio; CI: chlorophyll index; R-H/D: cutting height and stem diameter ratio; PC: phytosanitary condition; CL: clod length; and CA: clod angle.\*significant at 5% probability; NS: not significant.

provided adequate water assimilation, without adverse consequences for the plants. However, Freitas et al. (2005) assessed eucalyptus growth at two months and emphasized that the persistence of root deformations after planting can reduce or delay plant growth in the field, which, according to Figueiredo et al. (2014), occurs because it interferes in the hydraulic conductivity of the roots and consequently water and nutrient assimilation. In fact, the acquisition of water by the root system and the transport of this molecule throughout the plant establishes a flow (Tyree, 2003), which is originated by the evaporative demand of the tree canopy, constituting a soil-plant-atmosphere hydraulic continuum (Nikolova et al., 2009). Therefore, the greater hydraulic conductivity of the root is a crucial factor in the supply of water to the aerial part of the plant. According to Tyree & Zimmermann (2002), the anatomical characteristics of the root system may have an impact on the hydraulic conductivity of this organ. Huang & Eissenstat (2000) and Solari et al. (2006) also reported that differences in hydraulic conductivity may be related to root anatomy.

The phytosanitary condition correlated positively with growth in height of the plants at 12 and 24 months after planting, showing the importance of planting healthy cuttings. It is emphasized that the occurrence of diseases in cuttings can result in leaf abscission and consequently reduced photosynthesis rates (Alfenas et al., 2009; Carvalho, 1992; Gomes & Paiva, 2006).

Indeed, science has shown the importance of cutting quality for successful planting and increase in yield. However, for decision making on a set of characteristics for nursery outplanting, there are few studies that cater specifically to each species, nursery management and edaphoclimatic conditions in the planting sites.

#### 4. CONCLUSIONS

The parameters assessed in the nursery that correlated positively with growth in the field at three and six months after planting were height, number of leaf pairs, number of root deformations and clod length. Negative correlations were stem diameter, the canopy length and shoot height ratio.

At 12 and 24 months after planting, the parameters that correlated positively with field growth were height and phytosanitary condition, while the stem diameter,

number of leaf pairs and number of root deformations presented inverse correlation.

Although there was significant correlation, the root deformations did not interfere in the initial groups (three and six months) of the plants under high rainfall conditions, but the effects became harmful over time (12 and 24 months), resulting in reduced plant growth.

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#### CORRESPONDENCE TO

**Fábio Afonso Mazzei Moura de Assis Figueiredo**

Universidade Estadual do Maranhão (UEMA),  
Cidade Universitária Paulo VI, Departamento de  
Zootecnia, Av. Lourenço Vieira da Silva, 1.000,  
Jardim São Cristovão, CEP 65055-310, São Luís,  
MA, Brasil

e-mail: figueiredo.uema@gmail.com

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