ROOTING OF *Ficus enormis* MINI-CUTTINGS WITH DIFFERENT LENGTHS

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Resumo

Enraizamento de miniestacas de Ficus enormis com diferentes comprimentos. Ficus enormis é uma espécie nativa com grande potencial ecológico, em especial para atividades de restauração de ecossistemas florestais. O presente estudo objetivou avaliar o enraizamento, vigor radicial e vegetativo de miniestacas de Ficus enormis e determinar o seu melhor comprimento para a formação de mudas. Miniestacas caulinares foram coletadas de minijardim clonal, preparadas com 2±0,2 cm, 4±0,2 cm, 6±0,2 cm, 8±0,2 cm e 10±0,2 cm de comprimento e diâmetro de 0,5±0,2 cm. O plantio foi realizado em caixas plásticas preenchidas com substrato comercial a base de casca de arroz carbonizada e fibra de coco, acondicionadas em casa de vegetação. Após 45 dias foram avaliadas a porcentagem de enraizamento, manutenção de folhas originais, porcentagem de miniestacas com raízes e calos, comprimento das três maiores raízes/miniestaca, porcentagem de emissão de brotos, número de raízes/miniestaca e porcentagem de mortalidade. Os resultados demonstram que o comprimento das miniestacas não influencia a porcentagem de enraizamento, manutenção de folhas, formação de calo e raiz e comprimento médio de raízes. Já a emissão de brotações, número de raízes e mortalidade foram influeciadas pelo comprimento das miniestacas.
Palavras-chave: propagação vegetativa; espécie florestal nativa; recuperação de áreas degradadas.

Abstract

Ficus enormis is a native species with great ecological potential, especially for ecosystems restoration. The present study aimed to evaluate the rooting, root and vegetative vigor of Ficus enormis mini-cuttings and to determine its best length for the formation of seedlings. Mini-cuttings were collected from clonal mini-garden, prepared with 2 ± 0.2 cm, 4 ± 0.2 cm, 6 ± 0.2 cm, 8 ± 0.2 cm and 10 ± 0.2 cm of length and diameter of 0.5 ± 0.2 cm. The planting was carried out in plastic boxes filled with commercial substrate based on carbonized rice hulls and coconut fiber, conditioned in a greenhouse. After 45 days, were avaluated the rooting percentage, original leaf maintenance, mini-cuttings with roots and callus percentage, length of the three largest roots/mini-cutting, shoot emission percentage, number of root/mini-cutting and mortality percentage. The results showed that the mini-cuting length did not influenced the rooting percentage, callus and root formation, and root length mean. However, shoot emission, number of root and mortality were influenced by the mini-cutting length.
Keywords: vegetative propagation; native forest species; degraded areas recovery.

INTRODUCTION

Popularly known as the Fig Tree, *Ficus enormis* Mart. ex Miq. belongs to the Moraceae family and has a wide natural distribution in Brazil, where it is found in the phytogeographic domains of the Atlantic forest, Cerrado and Pantanal biomes (CARVALHO, 2006). Considered a species of great ecological potential, *F. enormis* presents intimate relationships with fauna and flora, serving as shelter and food for animals, as well as a structural support for orchids, bromeliads and other epiphytes (FIGUEIREDO, 1995). Environmentally, this species is important for the restoration of degraded ecosystems due to its nucleating characteristics, besides its fruit production during many months of the year, which attracts dispersal fauna (FRAGOSO *et al*., 2016).

For ecosystem restoration activities, producing seedlings of species with high ecological potential is indispensable. However, in some cases seminal propagation is limited, as it is difficult to obtain seeds, there can be low germination and silvicultural practices may be unknown (CARPANEZZI; CARPANEZZI, 2006). Species like *F. enormis* present difficult and laborious seedlings production due to the small size and high percentage of unviable seeds (CARVALHO, 2006).

In these cases, if applied consistently, vegetative propagation could be an excellent alternative for plants production for environmental purposes, supplanting the lowest genetic variability by using a larger number of matrices to produce initial propagules (WENDLING *et al*., 2005; CARPANEZZI; CARPANEZZI, 2006). The challenges for vegetative propagation include overcoming the effects of maturation in woody species, which are seen in physiological and biochemical alterations of donor plants (OSTERC; ŠTAMPAR, 2011), with consequent losses in rooting capacity (OSTERC; ŠTAMPAR, 2011; WENDLING *et al*., 2014) and root vigor (STUEPP *et al*., 2017).

Using plantlet production techniques such as mini-cuttings has evolved the vegetative propagation of woody species, especially by reducing the effects generated by maturation in those species with high ontogenetic age (STUEPP *et al*., 2017). The mini-cuttings technique has not yet been reported for *F. enormis*, however, cuttings were efficient in rooting and producing quality plantlets for the species (FRAGOSO *et al*., 2016).

Another factor that has been shown to be preponderant for rooting is the length of propagules. In stem cuttings, this factor varies according to the species studied, and its effectiveness in longer cuttings can be explained by the higher carbohydrate levels present in larger propagules (SIVACI, 2006; COSTA *et al*., 2013), destined for biosynthesis of acids and proteins required for the rooting process (ASLMOSHTAGHI; SHAHSAVAR, 2010). For *F. enormis,* the results of rooting and plantlets quality were satisfactory with cuttings of 8 ± 1 cm in length, while in mini-cuttings this length tends to be reduced due to the nutritional conditions available for mini-stumps in a mini-clonal garden (STUEPP *et al*., 2016).

Thus, our objective was to evaluate the rooting potential, as well as the root and vegetative vigor of *Ficus enormis* mini-cuttings and determine the best length of mini-cuttings for plantlets formation.

MATERIAL AND METHODS

The experiment was conducted between January and February 2017, on the premises of the Forest Species Propagation Laboratory, from Embrapa Florestas, in Colombo-PR (25°20' S and 49°14' W, 950 m). To produce propagules, mini-stumps of *F. enormis* matrices taken from a clonal garden in the field were used (FRAGOSO *et al*., 2016), which were cultivared in a semi-hydroponic system (mini-clonal hedge) stablished with medium size sand (Figure 1 A), with 20 cm x 20 cm spacing, in May of 2013. The mini-clonal hedge was located in a greenhouse covered with polyethylene, where mini-stumps received drip fertigation three times a day at an average flow rate of 6 L m^{-2} day^{-1} with the nutrient solution adapted from Wendling *et al*. (2007), consisting of monoammonium phosphate (0.065 g L^{-1}), magnesium sulfate (0.40 g L^{-1}), potassium nitrate (0.44 g L^{-1}), ammonium sulfate (0.2 g L^{-1}), potassium sulfate (0.07 g L^{-1}), calcium chloride (0.40 g L^{-1}), boric acid (2.88 mg L^{-1}), manganese sulfate (3.70mg L^{-1}), sodium molybdate (0.18mg L^{-1}), zinc sulphate (0.74mg L^{-1}) and hydroiron powder with 6% of iron (81.80 mg L^{-1}), replaced every two weeks.

For the formation and maintenance of the mini-clonal hedge, mini-stumps were subjected to successive and selective collections, ie, shoots smaller than 15 cm in length and with less than three pairs of leaves were kept for subsequent collections, which were carried out until November 2016. For the present study, mini-cuttings of the shoots produced by mini-stumps were prepared with 2 ± 0.2 cm, 4 ± 0.2 cm, 6 ± 0.2 cm, 8 ± 0.2 cm and 10 ± 0.2 cm lengths and 0.5 ± 0.2 cm diameters. A bevel cut was made at the base and just above the last terminal bud, keeping a leaf with 1/3 of its original surface area in the terminal portion (Figure 1). For mini-cuttings rooting, plastic boxes filled with commercial substrate of carbonized rice husks and coconut fiber were used. The mini-cuttings (base) were buried about 1 cm deep in the substrate, which were placed in a climatized greenhouse.

After 45 days, the following variables were evaluated: rooting percentage (live mini-cuttings with at least 2 mm long roots); maintenance of original leaves in mini-cuttings (mini-cuttings with original leaves in the rooting bed); percentage of mini-cuttings with roots and callus (live mini-cuttings with at least 2 mm long roots and formation of undifferentiated cell mass at the base); length of the three largest roots/mini-cuttings (cm); percentage of shoots emitted (mini-cuttings with new shoot emission of at least 2 mm length); number of roots/mini-cutting; percentage of mortality (mini-cuttings with necrosed tissues).

The experiment was carried out according to a completely randomized design, with five treatments (length of the mini-cuttings) and four replications, containing 20 mini-cuttings per experimental unit. The variances of the treatments were evaluated for homogeneity by the Bartlett test, and the variables that showed significant differences by the F test had their averages compared by the Scott-Knott test at a 5% probability level

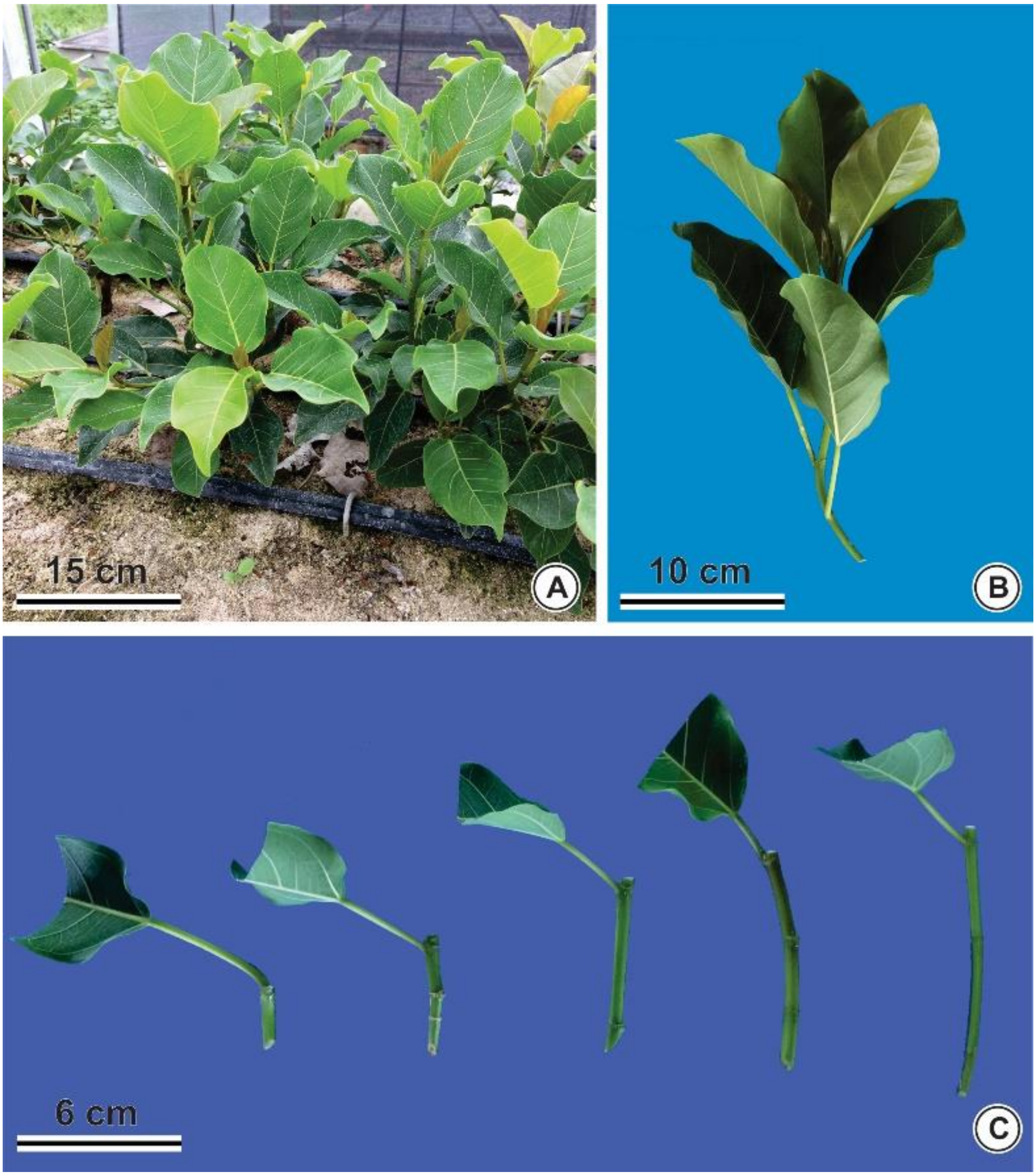

Figure 1. Schematic sequence of the mini-cuttings technique used in *Ficus enormis*: overview of the mini-clonal hedge (A), shoot collected (B), mini-cuttings lengths used for the experiment (2, 4, 6, 8 and 10 ± 0.2 cm, from left to right) (C).

Figura 1. Sequência esquemática para aplicação da técnica de miniestaquia em *Ficus enormis*: visão geral do minijardim clonal (A), broto coletado (B), comprimentos de miniestacas caulinares utilizadas para o experimento (2, 4, 6, 8 e 10±0,2 cm, da esquerda para direita) (C).

RESULTS

The results of the analysis for percentage of rooted mini-cuttings, leaf maintenance, mini-cuttings with callus and root and average root length of *Ficus enormis* showed no significant differences between the evaluated treatments (Table 1). For bud emmision, number of roots per mini-cutting and percentage of dead mini-cuttings we verified an effect of mini-cuttings length (Figure 2).

Table 1. Mini-cuttings length, rooting, leaf maintenance, roots and callus and avarage root length in *Ficus enormis* stem mini-cuttings, after 45 days of planting.

Tabela 1. Comprimento da miniestaca, enraizamento, manutenção de folhas, raízes e calos e comprimento médio de raízes em miniestaca caulinares de *Ficus enormis*, aos 45 dias após plantio.

Mini-cutting length (cm)	**Rooting (%)** [(ns)]	**Leaf Maintenance (%)** [(ns)]	**Roots and Calluses (%)** [(ns)]	**Average root length (cm)** [(ns)]
2	90,00	77,50	81,25	7,35
4	87,50	63,75	70,00	6,13
6	91,25	72,50	66,25	6,52
8	72,50	52,50	72,5	6,60
10	78,75	61,25	77,5	7,70
Average	84,00	65,50	73,5	6,86
CV%	13,87	19,95	26,72	19,73

CV%: Coefficient of variation; (ns): Not significant by the Scott-Knott test at 5% probability.

The rooting percentage ranged from 72.50% in mini-cuttings of 8 cm to 91.25% in mini-cuttings of 6 cm. Although no significant differences were observed between the different mini-cuttings lengths, it was possible to verify that shorter mini-cuttings tended to present higher rooting percentages (Table 1). In addition, a rooting average of 84.00% was observed, which is an excellent value for the production of plantlets of native species.

For original leaf maintenance of the mini-cuttings after 45 days, there was a variation between 77.50 and 52.50%, regardless of the size of the mini-cutting (Table 1). Callus formation was observed in practically all rooted mini-cuttings, with values between 81.25 and 66.25% for mini-cuttings with roots and calluses present (Table 1). The average length of roots ranged from 6.13 cm to 7.70 cm, respectively, in the mini-cuttings of 4 cm and 10 cm (Table 1).

The highest percentages of new shoot emissions were observed in 2 cm, 6 cm and 4 cm mini-cuttings, presenting 92.25%, 92.50% and 88.75%, respectively, which were statistically higher than those with 10 cm and 8 cm (Figure 2-A).

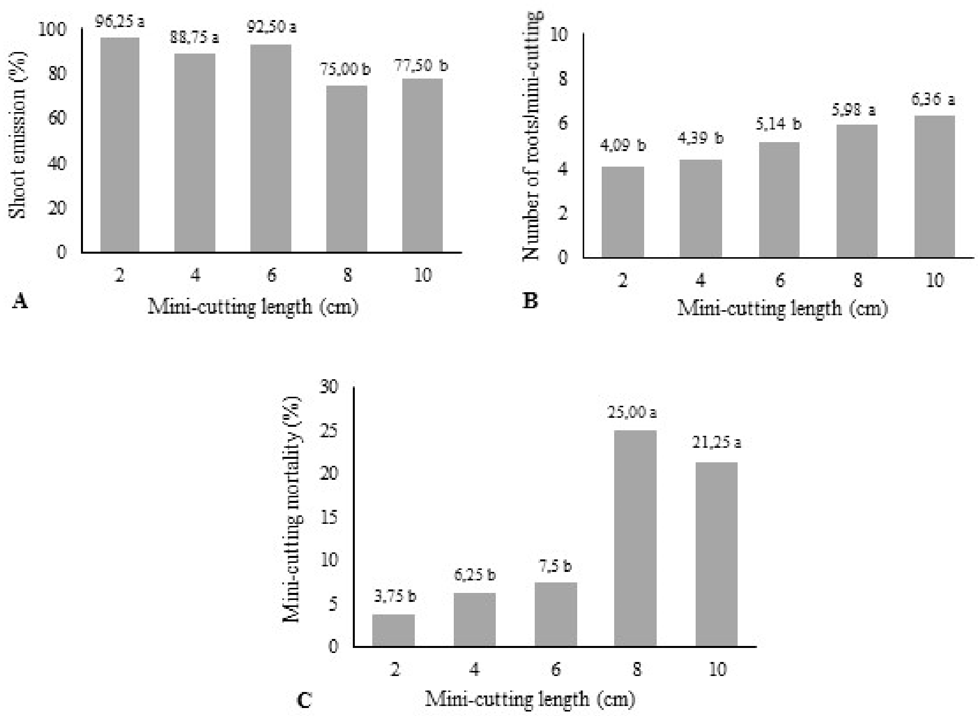

Figure 2. Shoot emission percentage (A), number of roots per mini-cutting (B) and mini-cutting mortality percentage (C) in relation to the length of *Ficus enormis* mini-cuttings, after 45 days of planting.

Figura 2. Porcentagem de emissão de brotos (A), número de raízes por miniestaca (B) e porcentagem de miniestacas mortas (C) em relação ao tamanho de miniestacas de *Ficus enormis*, aos 45 dias após plantio.

The number of roots per mini-cutting was influenced by their length, and the 10 cm and 8 cm mini-cuttings presented averages of 6.36 and 5.98 roots, respectively, which is superior to the other treatments (Figure 2-B). The mortality of mini-cuttings was higher in those of 8 cm (25.00%) and 10 cm (21.25%) (Figure 2-C).

DISCUSSION

The mini-cuttings technique aiming propagation of ecological interest species has generated satisfactory results, such as those observed in the works developed for *Calophyllum brasiliense* (SILVA *et al*., 2010), *Liquidambar styraciflua* (WENDLING *et al*., 2010) and *Piptocarpha angustifolia* (STUEPP *et al*., 2017). According to Xavier *et al*. (2003) the mini-cuttings technique provides higher quality, higher velocity and higher rooting percentages for propagules when compared to the conventional cuttings technique. The application of the mini-cuttings technique helps maintain the juvenile vigor of matrices, directly affecting the capacity and rooting vigor of propagules (HARTMANN *et al*., 2011; WENDLING *et al*., 2014), as greater juvenility tends to lead to higher rooting percentages (XAVIER *et al*., 2009).

The present study presented high rooting percentages (Table 1), highlighting the efficiency of using juvenile materials in the vegetative propagation of *Ficus enormis*, making exogenous sources of auxin for mini-cuttings rootingof this species unnessecary. Before visible morphological alterations, the complex adventitious rooting process involves molecular and biochemical factors that induce root formation and establishment and may be affected by radiation, temperature, hormones and carbohydrates (DE KLERK, 2002; RUEDELL *et al*., 2012).

The influence of cuttings and mini-cuttings length on the rooting of vegetatively propagated plants seems to depend on the species, which can directly influence the capacity of plantlets formation. In species of the *Eucalyptus* genus, mini-cuttings techniques have considerably increased the productivity, uniformity and the rooting percentage of propagules (MORAES, *et al*., 2014). Oliveira *et al*. (2008) observed that for *Melaleuca alternifólia* the 10 cm long cuttings presented superior rooting in relation to 15 cm and 20 cm cuttings. In *Pinus taeda,* root formation proved to be more efficient when using cuttings between 5.1 to 7.6 cm long rather than longer cuttings (FOSTER *et al*., 2000). Thus, the high rooting percentage in 2cm mini-cuttings (90%) should be stressed, which considerably increases the production of propagules and, consequently, plantlets production of the species.

Leaf maintenance in mini-cuttings favors rhizogenesis (HARTMANN *et al*., 2011), suppling carbohydrates and hormones indispensable to rooting (XAVIER *et al*., 2009). Carbohydrates do not directly regulate rooting but are energy sources used to synthesize other essential substances that induce adventitious roots, and may favor the effect of auxins, hormones directly related to root emission (HARTMANN *et al*., 2011). According to Fragoso *et al*. (2015), the importance of leaf maintenance in rooting of *Prunus serrulata* cuttings is clear. Furthermore, the increase in the average number of roots emitted by mini-cuttings (Table 1) associated with the increased length of mini-cuttings can be attributed to the greater number of reserves in such longer ones, favoring new root formation (HARTMANN *et al*., 2011).

The high percentage of mini-cuttings with callus presence indicates a possible relationship with adventitious root formation, since almost all of the rooted mini-cuttings presented roots and callus (Table 1). This premise is not always observed, as in the study developed by Lima *et al*. (2009) about *Maytenus ilicifolia*, where roots primordia did or did not originate from regions with callus, and callus formation was not considered a prerequisite for root formation. This factor is mentioned by Hartmann *et al*. (2011), who affirm that in difficult rooting species roots can form from the callus, although root formation is not a prerequisite for adventitious root formation, which may be a characteristic of each species (STUEPP *et al*., 2013; FRAGOSO *et al*., 2015).

After 45 days in a greenhouse, the high percentage of shoot emission was very close to the results verified for the emission of adventitious roots in the mini-cuttings (Table 1 and Figures 2-A). This fact is possibly due to the high vigor of *Ficus enormis* mini-cuttings, since the short period required for adventitious root emission favors the availability of solutes to continue the photosynthetic process. According to Dias *et al*. (2011), increased stem sugar content may indicate that it acted as a source of photoassimilates and, including soluble sugars, to promote sprouting (HARTMANN *et al*., 2011). It should be emphasized that the mini-cuttings technique favors the juvenility maintenance of these propagules, thus reducing the effects generated by maturation in woody species (FRAGOSO *et al*., 2016; STUEPP *et al*., 2017).

It was possible to verify a close relationship between the percentage of shoot emission and mortality of the mini-cuttings, with lower percentages of shoot emission associated with higher mortality percentages (Figure 2-A and C). Leaf maintenance can also be a contributing factor for these results (Table 1), since their early loss prevents the transport of rooting substances to the base of mini-cuttings, resulting in a lower efficiency in the induction of adventitious roots and higher mortality of mini-cuttings. Another important factor observed in the present study was that low mortality was observed in shorter mini-cuttings, again demonstrating the potential for increased productivity (multiplication rate) of propagules and clonal plants of species.

In general, the results presented in this study demonstrate the importance of using properly produced plant propagules for the rooting of *Ficus enormis*, especially with regarding vigor and juvenility. Moreover, it is noted that the mini-cuttings technique is efficient in the vegetative propagation of this species and can also be used as a reference for the propagation of woody species with limited vegetative propagation potential.

CONCLUSION

According to the conditions of this experiment, we conclude that:

- Rooting and root vigor in mini-cuttings of *Ficus enormis* are not influenced by mini-cuttings length.
- The number of roots and shoot emission are influenced by the mini-cuttings length.

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