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Mini-cuttings of forest and fruit species

Miniestaquia de espécies florestais e frutíferas

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Abstract

Mini-cutting is an important alternative for the production of seedlings of forest and fruit species. The technique is seen as an improvement in cutting, displaying variations for optimizing both the rooting and the quality of clonal seedling. Through this technique it is possible to propagate genotypes with superior characteristics, make better use of the parent plant, and overcome the difficulties of seed propagation. In this context, this review will address the use of vegetative propagation from mini-cuttings of forest and fruit species, highlighting the main advantages of this technique and the use of exogenous inducers and substrates for maximum rooting of seedlings. Despite the potential of minicutting for the propagation of different species, research is still needed so that new knowledge helps to expand its use in agriculture.

Additional keywords: hormonal regulators; forestry; fruit crops; substrates.

Resumo

A miniestaquia é uma importante alternativa para a produção de mudas de espécies florestais e frutíferas e é tida como um aprimoramento da técnica da estaquia, apresentando variações na metodologia para a otimização do enraizamento e da qualidade da muda clonal. Por meio deste método é possível propagar genótipos com características superiores, maior aproveitamento da planta matriz e superar as dificuldades da propagação via semente. Diante deste contexto, esta revisão irá abordar o uso da propagação vegetativa por meio de miniestaquia em espécies florestais e frutíferas, evidenciando as principais vantagens desta técnica, o uso de indutores exógenos e substratos para o máximo enraizamento das mudas. Apesar do potencial da miniestaquia para a propagação de diferentes espécies, ainda é necessário continuar as pesquisas para que novos conhecimentos ajudem a expandir o uso da miniestaquia na agricultura.

Palavras-chave adicionais: fruticultura; reguladores hormonais; silvicultura; substratos.

Introduction

Asexual or vegetative propagation consists of the multiplication of plant parts such as cells, tissues, or propagules, giving rise to individuals genetically identical to the parent plant (Wendling et al., 2002). This is a technique applied on a large scale mainly due to its effectiveness in retaining the gains obtained in genetic breeding. The most commonly used methods of vegetative propagation are grafting, cutting, micropropagation, micro-cutting, and mini-cutting (Wendling, 2003). These methods are used in clonal propagation of reforestation species of economic importance, such as those of the genus *Eucalyptus*, and of environmental importance, considering the maintenance of native trees and fruit production.

The mini-cutting technique is seen as an improvement in cutting, displaying variations for optimizing both the rooting and the quality of clonal seedlings (Xavier & Silva, 2010). It has been used to propagate forest species, mainly eucalyptus (Brondani et al., 2010), pink cedar (Xavier et al., 2003), pine (Alcântara et al., 2007), and ipe (Oliveira et al., 2015), and fruit species such as guava (Marinho et al., 2009), soursop (Figueiredo et al., 2013), pitanga (Peña et al., 2015), papaya (Oliveira et al., 2018), and passion fruit (Carvalho et al., 2007).

A mini-cutting is obtained by removing shoots, and its length varies from two to six centimeters, depending on the size of the shoots emitted, the size of the leaves, and the phyllotaxis of the species. The apex may or may not be kept intact, with two or four young leaves, with a straight or bevel cut at the base.

The turgor of mini-cuttings is maintained by placing them in containers with water, and phytosanitary treatments can often be dispensed with, since the environment where mini-cuttings develop is strictly controlled (Ferriani et al., 2010). Several factors interfere with the rooting of mini-cuttings, such as temperature, humidity, luminosity, substrate, maturity and rejuvenation capacity, time of year, nutrition and physiological/environmental conditions of the parent plant, phytohormones and genetic factors, and endogenous level of inhibitors. Thus, rooting success depends on the interaction between these factors, the possibility of manipulating them, and the knowledge and need of the species (Gatti et al., 2011).

Among the advantages of using mini-cuttings compared to conventional cuttings, the following stand out: reduction of the area necessary for the formation of the clonal garden, generally established in containers in the nursery itself; reduction in the cost of shoot collection and transport; greater efficiency in management (irrigation, nutrition, maintenance, and disease control). Moreover, using this technique provides greater rooting quality, rooting speed, and rooting potential (Xavier et al., 2003). Despite the advances obtained in the last three decades, vegetative propagation by mini-cutting has still been limited by factors such as lack of efficient methods for rejuvenating adult materials, lack of vegetative materials at an appropriate stage for vegetative propagation, lack of techniques for managing the propagation environment, and scarcity of studies emphasizing factors relevant to rooting (Dias et al., 2012).

This review presents and discusses studies carried out with the use of vegetative propagation from mini-cuttings of forest and fruit species, highlighting the main advantages of this technique and the use of exogenous inducers and substrates for maximum rooting of seedlings.

Mini-cutting in the production of forest species seedlings

The first studies using the mini-cutting technique in vegetative propagation were carried out with species of the genus *Eucalyptus* in the 1990s. The technique was chosen due to limitations in the production of seedlings of these species by conventional cuttings of certain clones, mainly with regard to adult materials, variations between clones, factors related to rooting, quality of the root system, and *in vitro* culture (Wendling, 2003; Melo et al., 2011). The principle for using mini-cuttings was related to improving and maximizing the production of vigorous eucalyptus seedlings, aiming to establish a less costly method with successive rooting of shoot tips, promoting rejuvenation and improving the rooting potential (Wendling, 2003). Advances in this technique have then allowed the growth of clonal forestry worldwide (Almeida et al., 2007).

From the last decade of the 21st century, mini-cutting has become the most widely used method of propagation by Brazilian forestry companies for the cloning of *Eucalyptus* (Almeida et al., 2007), being expanded to other areas, such as floriculture and fruit crops. The advantages of this technique in the production of eucalyptus seedlings have expanded its use for the production of seedlings of native species. It is especially used for the multiplication of new genotypes or when the availability of seeds of a given parent is low, or even under difficulties in storage and/or germination (Dias et al., 2012).

In addition to the production of eucalyptus seedlings, this technique has potential for application in other woody species of forest interest, such as pine (*Pinus taeda* L.). The mini-cutting technique increases the rooting of this species, providing a vigorous, uniform, and bulky root system, which favors the survival rate of plants in the field. Furthermore, some factors can directly influence root formation, such as collection time and juvenility. A proper balance between these factors and the use of plant growth regulators favors root performance and the formation of seedlings (Alcântara et al., 2007).

For araucaria (*Araucaria angustifolia*), seedling production from cuttings is limited in commercial production due to the difficulty of rejuvenating adult material and the plagiotropic growth of shoots. Mini-cuttings, in turn, form orthotropic seedlings with excellent rooting, denoting the potential of this technology for cloning. This suggests juvenile mini--cuttings as an alternative for the production of orthotropic propagules and, consequently, for the formation of normal seedlings (Pires et al., 2013).

Mini-cutting application has been shown to be technically feasible for the production of seedlings of jequitibá (*Cariniana estrellensis* (Raddi)), especially when the quantity of seeds is limited or when there are few individuals. The technique can be used in genetic breeding programs of this species. In addition, the use of plant growth regulators such as NAA and IBA can increase rooting efficiency (Gatti et al., 2011).

Some forest species have recalcitrant seeds, undefined harvest time, and high rate of cross-fertilization leading to great genetic variability between and within progenies. This is the case of red angico (*Anadenanthera macrocarpa* (Benth.) Brenan), in which production of mini-cuttings using juvenile material showed rooting efficiency without the need for exogenous regulators (Dias et al., 2012). This species has a natural aptitude for rooting of mini-cuttings, dismissing the use of growth regulators to induce adventitious roots. Another example is canjerana (*Cabralea canjerana* (Vell.) Mart.), a species native to Brazil, widely used in the reforestation of degraded areas and in the furniture industry. Nonetheless, seed recalcitrance in this species is an obstacle for seedling production. Mini-cuttings, in turn, are suitable for mass production of seedlings for the establishment of plantations of selected clones, aiming to improve the management and growth of this species. Still, the interaction between survival, rooting rate, and clone in the adaptation to production systems requires acclimatization of rooted mini-cuttings (Gimenes et al., 2015).

Seeds of some species such as purple ipê [*Handroanthus avellanedae* (Lorentz ex Griseb.) Mattos], although orthodox, are difficult to store, which decreases their germination potential. Thus, the mini-cuttings system favors the commercial production of seedlings, in addition to providing traits such as seedling uniformity in the nursery (Oliveira et al., 2015). Moreover, plant growth regulators such as IBA are not necessary for rooting; however, they should be considered for the production of purple ipê seedlings from mini-cuttings according to their destination, be it reforestation or recovery of degraded areas, as this species needs vigorous roots to survive environmental stress.

Production of seminal seedlings of vinhático (*Plathymenia foliolosa* Benth.) has been limited due to low germination rate. In this sense, vegetative propagation of mini-cuttings for this species has been gaining particular importance in the multiplication of heterozygous genotypes with desirable characteristics for the furniture industry. Some factors inherent to the characteristics of mini-cuttings, such as maintenance of leaves, are important for the rooting efficiency and survival of propagules. This is highlighted when there is no leaf reduction, which facilitates plant management, optimizes seedling preparation time, and reduces costs (Neubert et al., 2017).

Guanandi (*Calophyllum brasiliensis* Cambess) is a species native to Brazil, occurring from the Amazon region up to the north of Santa Catarina State. The species has a limited seedling production from seeds due to irregularity in obtaining seeds during the year, great variation in the germination rate, and the long period to germinate, reaching up to 145 days. Therefore, vegetative propagation from mini-cuttings stands as an alternative for the production of this species. A high rooting rate indicates rooting potential and the efficiency of the technique in producing seedlings for commercial purposes. The use of seedlings with little lignification tends to increase efficiency in homogeneous rooting of minicuttings, since these tissues have a higher degree of differentiation and less capacity to return to meristematic conditions, a fundamental factor for root initiation (Silva et al., 2010).

Canafístula (*Peltophorum dubium* (Spreng) Taub.) is a species native to southern Brazil. When harvested from ripe fruits, its seeds are dormant due to the high degree of dehydration, which causes slow and irregular germination. Thus, this species also presents potential for seedling production from mini-cuttings when managed in clonal mini-gardens (Mantovani et al., 2017). According to the authors, apical mini-cuttings have greater rooting potential. In addition, using the growth regulator IBA is not necessary for root induction, but stimulates root production.

Manacá-da-serra (*Tibouchina selowiana* (Cham.) Cogn), a species of ornamental importance, has low seed germination rates and a high degree of plant unevenness. Thus, rooting of lignified seedlings is complex, being preferable the use of mini-cuttings for presenting less lignification and greater endogenous hormonal balance, favorable to the emission of roots, which makes the technique viable for the production of seedlings of this species (Fragoso et al., 2017). As with other species, it is important to emphasize that satisfactory control of climatic conditions in the production environment is an essential factor for rooting success.

Harvest time, rooting environment, and the use of exogenous hormonal regulators are often essential criteria in improving the production of forest seedlings from mini-cuttings. Success is mostly guaranteed under joint control of these factors. It is also important to highlight that seedling yield increases are directly linked to the juvenility of the species. Using young tissues allows obtaining a vegetative material more responsive to adventitious rooting, often dispensing with the use of regulators (Hartmann et al., 2011).

In view of the high need for seedlings for the implantation of new forest stands and the difficulty in obtaining seedlings from seeds of native species for regeneration purposes, opting for the mini-cutting technique can be advantageous. The results of seedling production from mini-cuttings were promising for the species listed in the present study, with possibility for use in other species.

Mini-cuttings applied to fruit crops

In fruit crops, seedling formation is one of the most important stages in orchard establishment. Success is achieved when using techniques that aim to obtain vigorous and quality seedlings. The use of seeds in propagation is still common for some fruit species, as it is the only possible and viable method. Seeds are used when vegetative propagation is not viable, as in palm and *Arecaceae* species, or when this use does not bring genetic and economic losses, as in papaya, soursop, and passion fruit.

Using vegetative propagation in fruit crops is a consolidated reality that has advantages, especially for maintaining desirable genetic characteristics that can be transmitted for many generations. The main methods used are cutting, grafting, and micropropagation. Moreover, mini-cutting has been recently used successfully. This technique was initially adopted to overcome rooting difficulties and is currently being improved in the clonal propagation of many fruit species (Peña et al., 2015).

Facilities and restrictions of mini-cutting in fruit crops

The cultivation of peach (*Prunus persica* L. Batsch) cuttings propagation has been limited by some factors such as lack of appropriate techniques for managing the propagation environment, difficulties with nutrition, and post-rooting survival of cuttings. As a result, using mini-cuttings emerged as a promising alternative for improving rooting, which facilitated harvesting after transplanting mini-cuttings of root-stocks of important cultivars such as ‘Okinawa’. This technique enabled obtaining seedlings for rootstocks in the autumn and spring, with rapid formation of an adequate diameter for grafting (Tomaz et al., 2014). Furthermore, using the exogenous regulator indolbutyric acid (IBA) has positive effects on the rooting of herbaceous mini-cuttings of rootstocks of the peach cultivars ‘Nemared’ and ‘Flordaguard’, with maximum rooting being achieved with the dose of 1,590 mg L^{-1} (Timm et al., 2015).

For guava (*Psidium guajava* L.), cuttings propagation can be difficult when using a material with high degree of lignification, with differences in rooting ability within the same species. However, mini-cutting is regularly applied in commercial propagation of guava seedlings, being also used in breeding programs to select genotypes resistant to pests and diseases, improving the rooting of cultivars less likely to emit adventitious roots. Guava mini-cuttings prepared with an average length of 13.5 mm and after 35 days showed 100% rooting (Marinho et al., 2009). For cultivars ‘Paluma’, ‘Pedro Sato’, ‘Cortibel 1’, and ‘Cortibel 6’, the mini-cutting technique is suitable for seedling production, as it allows greater regrowth capacity of the mini-cuttings, increases the survival and rooting percentages of the mini-cuttings, and promotes seedling formation within the expected time and with adequate physical standards (Altoé et al., 2011). Responses varied with the cultivar, the size of mini-cuttings, and the rooting environment. For cultivars ‘Paluma’ and ‘Cortibel 6’, for example, the rooting of mini-cuttings varies with the environment to which they were exposed during the rooting period. Plastic mini-chambers can be used to cultivate ‘Paluma’, however, mini-cuttings of cultivar ‘Cortibel 6’ had a higher rooting rate in an environment with nebulizers (Milhem et al., 2014).

In the vegetative propagation of pitanga (*Eugenia uniflora* L.) from cuttings, the use of material from adult plants limits rooting, and conventional cuttings have a high degree of lignification. Using mini-cuttings in the production of pitanga seedlings can solve these problems, being an adequate option for obtaining juvenile vegetative propagules with high rooting rates and high quality roots. It is noteworthy that higher yields are obtained during summer. Moreover, both rooting and the quality of the root system improve by combining production with the use of IBA at doses close to 2,500 mg L^{-1} (Peña et al., 2015a). from pitanga grafts, grown in tubes, also prove to be an option for the production of propagules from mini-cuttings, with higher yields in hotter months (Peña et al., 2015b).

In cocoa (*Theobroma cacao* L.) propagation, the main advantages of replacing conventional cuttings with mini-cuttings are the high levels of rooting; the yield per parent plant; and reduced expenses with substrates, used in a smaller quantity. This technique enabled previous rooting and the transfer of mini-cuttings rooted between 40 and 60 days to tubes, reducing the losses that occur in direct rooting in screened nurseries (Sodré & Marrocos, 2009). In this context, seedlings of the cocoa clone ‘TSH 1188’ can be produced with mini-cuttings measuring between 4 and 8 cm in length without compromising quality (Sodré & Gomes, 2019).

Papaya (*Carica papaya* L.) seedlings are usually produced from seeds, given the ease of obtaining them. Notwithstanding, using new technologies such as mini-cuttings in the production of seedlings allows the selection of genotypes with desired characteristics and the implantation of a homogeneous area. Combining some factors such as substrate and application of hormonal regulators in an appropriate way makes mini-cutting an efficient method in the production of papaya seedlings. The use of vermiculite substrate and coconut fiber combined with the IBA dose of 0.5 mg L^{-1} led to successful rooting of mini-cuttings in a hydroponic system (Oliveira et al., 2018).

Another crop that adapts well to asexual propagation is passion fruit (*Passiflora edulis* Sims), whose seedlings are generally produced from seeds. The high variability of orchards propagated by seeds of uncontrolled origin, amplified by the self-incompatibility of this species, results in fruits that differ in size, color, weight, and pulp percentage, which can be devalued in the market. Furthermore, some commercial species are dormant (Meletti et al., 2002). Vegetative propagation of passion fruit is a means for the multiplication of productive plants that are tolerant/resistant to pests and diseases (São José, 1991). However, this method is not yet widely used in commercial seedling production due to higher costs and the time required for rooting in this species (Lima et al., 2011). Studies conducted from the rooting of herbaceous mini-cuttings of yellow passion fruit showed that characteristics inherent to mini-cuttings, such as maintaining leaves in the apex, increases the number of roots and root dry matter (Carvalho et al., 2007).

Asexual propagation of soursop (*Annona muricata* L.) is an advantageous alternative for maintaining the plant's genetic makeup and its uniformity in the field, reducing the vegetative period. The mini-cutting technique allows the use of propagules from parent plants grown both in nurseries and in the field (Figueiredo et al., 2013). These advantages can also be applied to the production of acerola seedlings (*Malpighia emarginata* Sesse & Moc. ex DC.), allowing the selection and multiplication of genotypes with superior agronomic characteristics, since sexual reproduction results in great genetic variability and unevenness of the orchard (Câmara et al., 2016).

Among the fruit species studied, the results found with the use of the technique have pointed out a great advantage in relation to conventional cutting. Mini-cutting thus consists of an alternative for the successful production of clonal seedlings of species whose conventional propagation is through seeds, such as papaya and passion fruit, thus allowing reduction of genetic variability within the orchard. In addition, production factors such as efficiency in the use of seedling production sites, formation of mini-gardens, reduction of management costs, quality of the root system, and rooting speed (Xavier et al., 2009) are advantages that allow for increased production in propagation from mini-cuttings.

Growth regulating substances and agents in propagation by mini-cuttings

Formation of adventitious roots depends on the endogenous levels of phytohormones, some of which are more favorable than others. Depending on the species, stage of maturity, and other factors such as nutrition, physiological and environmental conditions of the parent plant, genetics, and endogenous level of inhibitors, various substances, when applied to the seedling, promote or inhibit the initiation of adventitious roots (Goulart et al., 2008).

Among the most well-known growth regulators of interest in the vegetative propagation of plants, auxins stand out. The response of plants to endogenous or applied auxin may vary depending on the tissue and the concentration of this growth regulator already present in the propagule. When applied to isolated organs and depending on its concentration, auxin can increase the rhizogenic response to a certain extent, after which an inhibitory effect occurs (Taiz & Zeiger, 2004).

The inducing effect of auxins triggers rooting initiation close to the cut region of the seedling due to the polar transport of this regulator. Exogenous applications of growth regulators (mainly auxins) to vegetative propagules provide higher rooting percentage, rooting speed, and root system quality, although the recommended concentrations vary depending on the species, stage of maturity, environmental conditions, form of application, among other factors (Hartmann et al., 2011).

The advantages of IBA are low toxicity, more localized action than other products, and greater chemical stability in the cutting (Hartmann et al., 2011). At doses above 500 mg L^{-1}, IBA favors the survival and rooting of mini-cuttings of clones of *Eucalyptus grandis* W. Hill ex Maiden × *Eucalyptus urophylla* S.T. Blake. However, from 2000 mg L^{-1}, this regulator can be toxic for some clones. This effect was related to the high concentration of the regulator, which inhibited root formation and, consequently, reduced cutting survival.

For naphthalene acetic acid (NAA), doses between 500 and 1000 mg L^{-1} contributed to the survival of mini--cuttings of *Eucalyptus* clones, but the different doses did not interfere with the rooting of some clones; however, other clones showed sensitivity to this regulator. These responses may be mainly linked to genotypic differences and to the maturity of the material used (Goulart et al., 2008).

Clones of *Eucalyptus cloeziana* F. Muell with greater adventitious rooting potential respond more positively to lower IBA doses, while in clones with reduced rooting capacity there is a tendency for higher IBA doses to increase rooting efficiency. It is important to note that some clones, especially those with difficulty in adventitious rooting, show a plagiotropic tendency, which may vary depending on the juvenility of the propagules that gave rise to the plants. As the clones used were taken from mini-cuttings formed from 15-year-old trees, the effect of age could be affecting the rooting of seedlings. In general, NAA does not significantly influence the rooting of mini-cuttings of most *E. cloeziana* clones (Almeida et al., 2007).

The application of IBA in eucalyptus (*E. grandis* and *E. globulus* Labill.), red angico (*Anadenanthera macrocarpa*), and teak (*Tectona grandis* L.f.) did not increase the rooting and survival of mini-cuttings nor the vigor of seedlings, and some *E. grandis* clones showed toxicity at concentrations above 500 mg L^{-1} (Wendling & Xavier, 2005; Borges et al., 2011; Dias et al. 2012a; Badilla et al., 2016). However, there was an increase in rooting and survival rates of mini-cuttings at the doses of 1,000 and 2,000 mg L^{-1} in most *E. grandis* clones (Titon et al., 2003).

For soursop and pink cedar (*Cedrela fissilis* Vell.), IBA application had no effect on the rooting of mini-cuttings, and not applying this regulator provided better results (Xavier et al., 2003; Figueiredo et al., 2013).

In papaya, low IBA doses influenced the rooting of mini-cuttings, since the increase in IBA levels from 0 to 10 mg L^{-1} had a quadratic effect on rooting, survival, stem diameter growth, shoot growth, and length of the largest root, with the optimal dose of 5 mg L^{-1} for the development of mini-cuttings (Oliveira et al., 2018).

Application of IBA at the dose of 8,000 mg L^{-1} in seedlings of purple ipê did not show a significant effect on the rooting of mini-cuttings; however, its use promoted an increase in the number and length of roots (Oliveira et al., 2016). For araucaria, the increase in IBA concentrations promoted a small increase in the survival (up to 3,000 mg L^{-1}), number of roots (up to an estimated 2,300 mg $L^{-}1$), and rooting (up to 1,500 mg L^{-1}) of mini-cuttings (Pires et al., 2013).

Biofertilizers are organic compounds with a high concentration of nutrients in their formulation, showing hormonal action that can stimulate adventitious rooting (Medeiros et al., 2003). The use of biofertilizer in *E. benthamii* Maiden et Cambage mini-cuttings provided rooting of 51.6% to 65% and survival of 68.4% mini-cuttings. The best results were observed when immerging the mini-cuttings in the biofertilizer solution for 30 minutes (Mayer et al., 2018). For *E. urophylla* minicuttings, using the organic biofertilizer Fert-Bokashi® at doses of up to 1% did not influence the survival and growth of seedlings (Fernandes et al., 2011).

Nutsedge (*Cyperus rotundus* L.) is considered the most important weed in the world due to its wide distribution, capacity for competition, aggressiveness, and difficulty of control and eradication (Durigan et al., 2005). This weed has potential for rooting due to the confirmation of the presence of indoleacetic acid (IAA) in its composition (Meguro, 1969). There was an effect of nutsedge extract on the rooting of mini-cuttings of cacao. When compared to IBA at 6,000 mg L^{-1}, *Cyperus laxus* Lam extract at 100% concentration promoted greater rooting and increased the quality of cocoa seedlings, CCN-51 being the clone with the best response (Pereira, 2018).

In nature there are biological systems between plants and microorganisms, among which stand out symbioses between legumes and rhizobia, forming nodular nitrogen-fixing bacteria, of greater economic expression, and between legumes and arbuscular mycorrhizal fungi (AMF) (Siviero et al., 2008). These biological systems can be an alternative to reduce costs with phosphorus and nitrogen fertilizers in the production of seedlings.

Inoculation of arbuscular mycorrhizal fungi (AMF) and rhizobia to the substrate can improve the quality of mini-cuttings, since mycorrhizae aid in plant growth by: improving the absorption of nutrients, especially phosphorus; increasing the volume of soil explored; and increasing the tolerance to biotic and abiotic stresses (Khade & Rodrigues, 2009; Chaer et al., 2011).

Inoculation with rhizobia and arbuscular mycorrhizal fungi in red angico (*Anadenanthera macrocarpa* (Benth.) Brenan.) substrate provided mini--cuttings with the highest survival rate and the highest number of roots after 140 days. Symbiotic association with rhizobia and/or AMF favors the production of *A. macrocarpa* seedlings by mini-cuttings (Dias et al., 2012b). In promoting the growth and rooting of *E. dunnii* Maiden minicuttings, depending on the collection time, rhizobacteria isolates have either a beneficial or a deleterious effect on survival. These isolates have no effect on the rooting of mini-cuttings (Spassin et al., 2016).

Other fungi that have potential for the treatment of mini-cuttings are those of the genus *Trichoderma*. This genus comprises a large number of free-living filamentous fungal species found in various ecosystems, occurring from tropical to temperate regions (Brotman et al., 2010; Machado et al., 2012). Association of *Trichoderma* with roots promotes their growth through production of phytohormones, in addition to increased availability of nutrients and greater efficiency in their use by plants (Azarmi et al., 2011; Stewart & Hill, 2014).

Using *Trichoderma harzianum* and *T. virens* in the treatment of clonal mini-cuttings of *E. camaldulensis* Dehnh. increases the number of leaves, shoot dry matter, root dry matter, and total dry matter of plants. Regarding the treatment of minicuttings, *T. virens* proves to be more efficient in promoting seedling growth and quality than *T. harzianum*. The growth-promoting action of these microorganisms on plants is due to their ability to colonize roots, aiding in the assimilation of nutrients by plants (Azevedo et al., 2017).

Substrates for mini-cutting

In the production of seedlings from mini-cuttings, due attention must be given when choosing the substrate. The environment where the mini-cutting will be kept must provide the necessary conditions for the rooting and development of seedlings, considering the requirements of the species to be propagated. One of the advantages of the mini-cutting technique is that it allows the reduction of the substrate volume commonly used in the production of seedlings by conventional cutting, reducing costs (Xavier et al., 2009). Notwithstanding, few studies have compared the types of substrates for seedling production from mini-cuttings.

A study tested the production of eucalyptus seedlings from mini-cuttings conducted in tubes and in pressed blocks containing different substrates (sugarcane bagasse + filter cake in a 3:2 ratio; decomposed eucalyptus bark + carbonized rice husk in a 7:3 ratio; peat substrate, pressed in blocks). Based on all the biometric characteristics of the shoots of the evaluated plants, the use of sugarcane bagasse with filter cake accelerated seedling development (Freitas et al., 2006). In general, seedlings produced in a pressed block system showed faster growth, which is due not only to the absence of root restriction, but also to the fact that the substrate volume is greater than the capacity of the tube.

Two substrates (vermiculite and organic compound) and two types of mini-cuttings (apical and intermediate) were studied in the rooting of six half-brother progenies of red angico (*Anadenanthera macrocarpa*) from mini-cuttings of seminal origin. The apical mini-cutting grown with vermiculite provided higher values for the adventitious rooting of progenies (Dias et al., 2015). These results were due to the physical characteristics of the vermiculite, such as aeration and moisture retention. Thus, vermiculite provided better distribution and conformation of roots, expressing greater dry weight. Root weight is directly related to the volume and quantity of roots, essential factors for better development of seedlings after planting.

In another study, apical mini-cuttings of guanandi (*Calophyllum brasiliense*) were grown in three substrates: vermiculite, carbonized rice husk, and commercial agricultural substrate based on composted pine husk. The substrates were kept in a greenhouse for 30, 45, 60, 75, and 90 days. The vermiculite-based substrate directly influenced the rooting speed of mini-cuttings, with 95.8% rooting at 60 days in the greenhouse, while carbonized rice husk and composted pine husk showed a similar value only at 90 days (Silva et al., 2010). According to these authors, the best behavior attributed to vermiculite is related to its physical properties that favor aeration of the root system and moisture retention, providing uniform distribution in the development of adventitious roots.

Furthermore, IBA doses (0; 2.5; 5.0; 7.5; and 10 mg L^{-1}) and two substrates (vermiculite and coconut fiber) were tested in the rooting of mini-cuttings of the hybrid papaya UENF/CALIMAN 02. After 45 days, the IBA dose of 5.0 mg L^{-1} in the vermiculite substrate proved to be more suitable for the rooting of mini-cuttings. Vermiculite benefited rooting since it is a porous substrate. The use of IBA at high concentrations inhibited root growth, denoting the importance of adequate combinations, as in the case of the dose of 5.0 mg L^{-1}, which favored root performance (Oliveira et al., 2018).

Using a substrate with formulations and mixtures is an alternative to improve physical and chemical qualities with cost reduction. The use of formulations between renewable substrates with combinations between the substrates pine husk, vermiculite, and carbonized rice husk in the production of yerba mate (*Ilex paraguariensis* A. St. Hil.) seedlings from mini-cuttings is technically feasible, although substrates with balanced proportions of coconut fiber and carbonized rice husk have provided better rooting (Kratz et al., 2015). Fiber concentrations may have contributed to the higher values of root length, as such proportions favor a high substrate moisture inside the container, displacing the roots to their sides, favoring root elongation in search of better aeration conditions.

Final considerations

The mini-cutting technique has great potential for the propagation of forest species and some fruit species. However, additional research must be conducted for it to become viable with regard to the adequacy of protocols for different species. Research must aim at the rejuvenation of propagules to increase rooting potential, also comprising the use of growth inducers and the adaptation of management systems and propagation environments.

Mini-cutting appears as an important alternative for mass production of seedlings of forest and fruit species to supply the demands of agribusiness. It is important to highlight that through this method it is possible to propagate genotypes with superior characteristics, with greater use of the parent plant.

The viability of this technique guides criteria demonstrated in the mentioned works. An example is the exploration of the conduction systems, whether for forest or fruit species, involving the use of exogenous IBA regulators, the use of suitable substrates, collection time, and specific rooting environments. A minicutting is not only a small stem segment, but rather a technological package that requires attention for the success of its application.

From the reports, we conclude that the mini-cutting technique has potential for vegetative propagation of the species mentioned and new ones. However, research is still needed so that new knowledge helps to expand the use of mini-cutting in agriculture.

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