Sprouting and rooting ability of the plus trees of *Eucalyptus pellita*, *E. brassiana* and its hybrid in Wanagama, Indonesia

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**Abstract.** The demand for eucalypts has greatly increased since they are raw materials for timbers, plywood, pulp and papers, and essential oil production. This study aimed to select the plus trees and determine the sprouting and rooting ability of *E. pellita*, *E. brassiana*, and their hybrids in Wanagama. Plus trees selection and girdling were conducted in December 2019. Cuttings were picked from the 3rd-4th nodes of sprouting at 8-10 cm in length. A completely randomized design was applied in a factorial experiment with three levels of Indole Butyric Acid (IBA) (100, 1000, and 4000 ppm) and two types of media (media 1: sand, rice husk charcoal and cocopeat (2:2:1), media 2: sand, topsoil and dung-fertilizer (2:2:1)), with ten replications. Results selected a total of 53 plus trees candidates (29 of *E. pellita*, 12 of *E. brassiana*, and 12 of hybrid). *E. pellita* is the best in sprouting ability (100% survival; 41-60 shoot/trees, 127-161cm shoot length, 0.53-0.57cm shoot diameter, and 194-252 leaves/shoot). Cuttings of *E. pellita* treated with 100 ppm IBA gained the highest survival and leaves production (96%-100%; 14-16 leaves), followed by *E. brassiana* (52%-66.67%; 7 leaves) and the hybrid (4% to 8.33%; 3-4 leaves). These results may contribute to arranging better strategies for mass production of selected eucalypts.

1. **Introduction**

Eucalypts are endemic to Australia and the northern islands nearby [1, 2]. Eucalypts are important since they are adaptive, productive, fast-growing, short cycle, have long and straight fiber, are pruned easily, and are resistant [3]. They may grow in a wide range of climates and soils. However, it prefers sandy loam soil with a pH not less than 8 [4,5]. Recently, eucalypts have been widely cultivated in many parts of the world, including the temperate and subtropical regions, i.e., Brazil, Chile, Portugal, and Spain, until the tropical and arid regions, i.e., Asia and Africa [2, 4, 5]. Eucalypts is one of the priorities in forestry due to its three main functions, (1) raw materials for the timber and plywood industries [1, 3, 4], (2) raw materials for the pulp and paper industries [1, 3, 6-8], and (3) essential oil production [9-14]. The essential oil extracted from eucalypts consisted of 1.8 cineole [9 - 13] and jensenone [14], which had antiviral potentials against COVID-19. Therefore, the demand for eucalypts has greatly increased because it is materials for Covid-19 drugs and diffusers [9-14].

Eucalypts suitable for tropical regions and selected for a large-scale plantation are *Eucalyptus pellita*, *E. urophylla* and *E. alba* [1, 4]. *E. pellita* can accept pollen from other species and, therefore, is widely used in hybridization with other eucalypts. Other eucalypts eligible for crossing is *E. brassiana* which is highly adaptive and drought-resistant; and *E. urophylla*, which is fast-growing,
resistant to pests and diseases, having good wood quality, and having high wood biomass for pulps [1].

The importance of eucalypts enhances its domestication and genetic improvement program all over the world. Many breeding strategies were arranged to reproduce trees with the best performance. Furthermore, many propagation techniques were developed for mass propagation of the best trees, particularly by vegetative propagation. Since then, cross- and hybrid-breeding and clonal propagation have become the best strategies for designing the improvement program of eucalypts [2-4]. The genetic improvement program started with selecting trees with the best phenotypic performances well adapted to the targeted plantation area [2]. In addition, crosses and hybridization between best parents -- both intra- and inter-species -- were also conducted to gain better performances in offspring [15]. The hybrids usually have intermediate characteristics between the two parents, more like one parent, or even have better performance, known as heterosis or vigor hybrids. Offspring with superior traits can be selected as parent trees for mass propagation. The further step is developing the vegetative propagation techniques to arrange the clonal propagation strategy [2, 3]. Vegetative propagation is a multiplying tool that consolidates genetic gain [16], capturing desirable genes without recombination [2]. There are various methods of vegetative propagation include graftings, layerings, and cuttings. Among these techniques, the shoot cuttings are mostly applied in eucalypts. The applications of suitable hormones and media [2-5] and the addition of bio-fertilizers [17] can significantly increase the success of eucalypt cuttings.

The most cultivated eucalyptus hybrids are E. urophylla x E. grandis, which have been widely developed for planting in China, Congo, Brazil, and South Africa [2, 6]. In Congo, the hybrids of E. alba x E. grandis, and E. urophylla x E. grandis, may increase productivity from a range of 10-15 to 15-20 m³ ha⁻¹ yr⁻¹. The hybrid of E. camaldulensis x E. grandis may combine drought stress-adaptation and fast growth, and therefore are cultivated in the driest environment of South Africa and the central plateau of Brazil. The clones derived from E. globulus hybrids, the best wood quality species, have increased 20% of the use of wood for cellulose in Brazil. The best clones were selected in Spain by their drought-adaptation and resistance to Phoracantha pests [2]. However, several studies also reported lower performance of eucalypt hybrids compared to their parents. Many cases included the lower performances of several eucalypt hybrids in Brazil and Congo [2], the E. pellita x E. urophylla hybrids in Congo, the E. grandis x E. globulus hybrids in Uruguay, the E. urophylla x E. tereticornis hybrids in China [7], the hybrids of E. urophylla x E. grandis and E. grandis x E. camaldulensis in Kenya, Tanzania and Uganda [4], and the E. pellita x E. grandis hybrids in Sumatra [6].

Wanagama Forest Research Station, established in 1966, is a 600 ha artificial forest belonging to the Faculty of Forestry, Gadjah Mada University; located in the highlands of Gunungkidul about 40 km south of Yogyakarta [18]. Wanagama has started the conservation and improvement program on eucalypts since the year the 1980s; and therefore is considered eligible as a source of pure and hybrid eucalypts materials. The eight exotic eucalypt species (E. citriodora, E. torelliana, E. tereticornis, E. camaldulensis, E. alba, E. brassiana, E. urophylla, and E. deglupta) were planted in a species trial in 1985. There are also pure stands of E. pellita (1995), E. urophylla (1985), E. brassiana (1995), E. deglupta (1992), and E. alba (1985). Hybridization between the best five species resulted in the hybrids of E. urophylla x E. alba (1996), E. pellita x E. brassiana (1998), E. pellita x E. urophylla (2000), and E. urophylla x E. grandis (1996). Previous studies showed that E. tereticornis, E. deglupta and E. urophylla oil extracted from stands in Wanagama are effective as insecticides for Culex quinquefasciatus, the mosquito vector of filariasis. E. urophylla contains α-pinene (11.73%), 1,8-cineole (49.86%), β-ocimene (6.25%), γ-terpinene (9.11%), and α-terpinyl acetate (7.63%) [19]; while E. tereticornis and E. deglupta contain 24 and 35 content with β-pinene and nerolidol [20].

Since the demand on eucalypts for materials of construction woods, pulp and paper, and cineole is raised significantly [9-14]. Therefore it is considered essential to develop the planting material sources. Eucalypt plantations in Wanagama are projected to be converted into genetic resources that provide eucalypts’ superior genetic materials. Accordingly, the best parents are supposed to be selected
by evaluating the phenotypic characters and determining their reproductive ability. The pure E. pellita, E. brassiana, and their hybrid stands are assessed first since they performed better growth and phenotypic than the other eucalypt stands. This study aimed to select the plus trees for mass propagation and estimate the reproductive ability of plus trees of *E. pellita*, *E. brassiana*, and their hybrids in Wanagama.

2. Methodology

2.1. Study sites

The study was conducted in Wanagama Forest Research Station in Gunungkidul District, Yogyakarta Special Region (7°50'10" S to 110°50'80" E; 150 to 400 m above sea level). This area is a part of the Middle Zone of Gunung Sewu, representing a lowland basin landscape in Java Island. The rocks are carbonate sediments, dominated by limestone and marl with 2° to 10° slopes. Soils are dark-grey-brown latosols, heavy clay textured, and very attached with shallow topsoil. Most of the soil solum is less than 10-20 cm. Climate is intermediate between *Aw* and *Am* type, according to Schmidt and Fergusson. Rainfall is 1900 mm year⁻¹, lasts between 2 to 6 months of the year. The average temperature is 27.7°C with 80-90% air humidity [18].

2.2. Study materials

Materials used in this study were the plantation of *E. pellita*, *E. brassiana* and their hybrid. The *E. pellita* progeny trial was established in 1995 using seeds collected from its natural population in Papua. Previously, it consisted of 104 progenies with four tree plots, replicated in four blocks, with a 4 x 4 m spacing. However, due to a prolonged drought recently, only 313 trees were left.

The *E. brassiana* provenance stand was established in 1995 using bulk seeds collected from its provenance in Soe, Kupang, Nusa Tenggara Timur. Previously it consisted of 200 trees in a 4 x 4 m spacing. However, recently only 114 trees were left.

Hybridization was conducted in 1997 by selecting each of the best five parents in both *E. pellita* and *E. brassiana* stands. The five parents of *E. pellita* and five of *E. brassiana* were crossed reciprocally. In 1998, the seeds of the hybrid were collected and germinated. After eight months in the nursery, seedlings were planted using the Randomized Completely Block Design, consisting of 40 hybrid combinations with three tree plots, replicated in three blocks, with a 3 x 3 m spacing.

2.3. Methods

2.3.1. Plus tree selection for mass propagation. Plus trees selection was conducted in 2019 by a phenotypic assessment on both quantitative and qualitative characters according to the Ministry of Forestry Standard of Plus Tree Selection [21]. The characteristics measured included quantitative (tree height, branches-free stem height, and diameter at breast height; and qualitative (stem straightness, natural pruning, cylindricity, angle of branching, stem surface, and plant health). The maximum score is 100, and the tree can be selected for plus tree candidate when it scored equal to or more than 60.

2.3.2. Estimating the sprouting ability. In order to produce sproutings as a material for shoot cuttings, the stems of plus trees were girdled in December 2019. Girdling was conducted following [3] to cut the phloem transportation by making a circular incision on the stem, 20-30 cm length, 1-2 cm of depth, at 10-15 cm distance from the base of the tree. Sprouting ability was observed after two months by calculating the number and size of sproutings and the number of leaves in each sprouting.

2.3.3. Estimating the rooting ability. Shoot cuttings were prepared following the modified methods by [2, 12]. The shoots were picked from the 3rd and 4th nodes of sprouting at 8 to 10 cm in length. Meanwhile, cuttings were prepared with two nodes and a 50% reduction in leaf area. A completely randomized design was applied in a factorial experiment with three levels of Indole Butyric Acid (IBA) (100, 1000, and 4000 ppm) and two types of media (media 1: sand, rice husk charcoal and cocopeat (2:2:1), media 2: sand, topsoil and dung-fertilizer (2:2:1)), with ten replications. The basal portion of the cuttings was soaked in the IBA solution for 15 minutes. Cuttings were then planted in
polybags filled with media and placed into the rooting chamber covered with plastics. Chambers were placed under a 75% shade net, and watering was conducted four times a day. Rooting ability was observed after eight weeks by determining the leaves formation and survival rate of cuttings.

3. Results and Discussion

3.1. Plus tree selection for mass propagation

Phenotypic assessment has selected 29 trees of *E. pellita*, 12 of *E. brassiana*, and 12 of *E. pellita* x *E. brassiana* hybrid, which scored more than 60 and met the requirements for plus trees certification (Figure 1). Most of the candidates are selected from the *E. pellita* stand. Qualitative and quantitative scores are similar for *E. pellita* and *E. brassiana*, while the hybrid is scored somehow lower, particularly in quantitative characters (Figure 1a). *E. brassiana* has the smallest diameter but the highest stem and free-branches stem. Oppositely, *E. pellita* is the biggest in diameter but lower in stem and free-branches stem. Their hybrid has an intermediate level in diameter but the lowest in stem and free-branches stem (Figure 1b).

![Figure 1](image1.png)

**Figure 1.** Phenotypic assessment on *E. brassiana*, *E. pellita* and their hybrids: (a) the number of plus tree candidates along with their quantitative, qualitative and total scores; (b) the average of quantitative characters represented in diameter, stem height and free-branches stem height (m).

The best four in *E. pellita* are P96 (205), P618 (222), P451 (234), and P468 (202), while in *E. brassiana* are B105, B77, B107, B64. In hybrid stand, the B3P5, B3P1, B4P1, B5P1 hybrids performed the best phenotype (Figure 2). The B3 (the parent trees number 3 of *E. brassiana*) is the best for female parents, while P1 (the parent trees number 1 of *E. pellita*) is the best for male parents (data not shown).
(a) Rank 1 to 4 of *E. pellita*

P96 (205)  
P618 (222)  
P451 (234)  
P468 (202)

(b) Rank 1 to 4 of *E. brassiana*

B105  
B77  
B107  
B64

(c) Rank 1 to 4 of the hybrid of *E. pellita* x *E. brassiana*

B3P1  
B3P5  
B5P1  
B4P1

Figure 2. The best four in each of *E. brassiana* (a) *E. pellita* (b) and their hybrids (c).

Several studies revealed that the hybrids usually have intermediate characters between the two parents, more similar to one parent, or even perform better characters known as heterosis or vigor hybrids [2, 3, 4, 6, 15]. However, other studies also reported lower performance on eucalypt hybrids compared to their parents. In Brazil and Congo, several hybrids were against the expected heterotic performances [2]. *E. pellita* x *E. urophylla* hybrids in Congo performed lower growth and quality than the parents, which was thought to be due to the limited number of male parents. Several other lower-performance hybrids were the *E. grandis* x *E. globulus* in Uruguay and *E. urophylla* x *E. tereticornis* in China [7]. In Kenya, two types of hybrids, *E. urophylla* x *E. grandis* and *E. grandis* x *E. camaldulensis*, also performed lower performance. Tanzania and Uganda also show a similar trend. The best hybrids are *E. grandis* x *E. camaldulensis*; however, pure species of *E. urophylla* and *E. grandis* dominate superior performance [4]. In Sumatra, *E. urophylla* x *E. grandis* produced many vigor hybrids, while *E. pellita* x *E. grandis* are more susceptible to disease [6].

3.2. Estimating the sprouting ability

*E. pellita* dominated the highest result for all of the sprouting parameters observed, while in contrast, the hybrids performed the lowest sprouting ability (Figure 3). All of 29 girdled *E. pellita* trees (100%)
succeed in producing sproutings. In *E. brassiana*, only 9 out of 12 girdled trees (75%) were sprouted. The lowest sprouting ability was recorded in the hybrids, in which only 4 out of 12 girdled trees (33.3%) were able to produce sproutings (Figure 3a). *E. pellita* also performed the best result on the shoot number per tree (41-60 shoots; Figure 3b), shoot length (127-161 cm; Figure 3c), shoot diameter (0.53-0.57 cm; Figure 3d), and the leaves number per shoot (194-252 leaves; Figure 3e). The hybrid observed the opposite result, producing the lowest shoot number per tree, shoot length, shoot diameter, and leaves per shoot.

![Figure 3](image)

**Figure 3.** The sprouting ability of *E. brassiana*, *E. pellita* and their hybrids: the sprouting survival (%) (a), the shoot number per trees (b), the shoot length (cm) (c), the shoot diameter (cm) (d), and the leaves number per shoot (e).

It seemed that the differences in sprouting ability are under genetic control [2, 3, 16]. Several studies reported similar results in which sprouting ability differed among pure and hybrid eucalypt species. In Spain, over almost 2000 girdled hybrids, only 700 were able to produce sproutings, and
lately, out of 100 of these 700 trees survived. After several tests on sprouting and rooting ability, only 16 clones were finally selected for operational scale propagation [2].

The sprouting ability is influenced by internal factors such as plant age, genetic and hormonal factors, as well as external factors such as site conditions, microclimate, and various silvicultural actions in plants [22]. Other sources reported that the most important external factors are soil, light, humidity and water, while internal factors are genes, hormones, anatomical structures, plant organ morphology and chlorophyll content. For example, lack of light will result in a slow rate of photosynthesis which might inhibit the sprouting formation [23].

Different ages and genetic factors will result in different sprouting abilities. The *E. pellita* and *E. brassiana* stands in Wanagama were 25 years old when the study was conducted, while the hybrid was 20 years old. This age is still in the range which is considered capable of optimal reproduction, both sexually and asexually. At this age, the processes of photosynthesis, accumulation and distribution of photosynthate and cell division and elongation are at their best capacity [22]. Most species will experience a decrease in sprouting ability after 40 years of age. Sprouting capacity will also decrease after 3 to 5 generations. In India, the sprouting of *E. globulus* with a 15 years rotation was reduced by 9% in the 2nd rotation. It was further reduced to 20% in the 4th rotation [23]. In line with this, other studies showed that eucalypts of younger age might also produce lesser sproutings. The sprouting size obtained in this study (126.82 cm length in *E. pellita*, 82.02 cm in *E. brassiana*, and 78.29 cm in the hybrid at one month after girdling) is much larger than sprouting produced from 9 years old *E. pellita* in Riau, Sumatera (10.4 to 13.2 cm length at one month after girdling) [24]. More sproutings were reported in this study (41 shoots per tree in *E. pellita*, 29 shoots in *E. brassiana*, and 16 shoots in the hybrid at one month after girdling) compared to those nine-year-old *E. pellita* in Riau, Sumatera, which only produced 6 to 16 shoots per tree [24]. Similarly, more abundant leaves were reported in this study (194 leaves per shoot in *E. pellita*, 128 leaves in *E. brassiana*, and 84 leaves in the hybrid one month after girdling) compared to those nine-year-old *E. pellita* in Riau, Sumatera, which only produced 2 to 40 leaves per shoot [24].

The sprouting regeneration system is the activity of stressed or injured trees to stimulate shoots emergence on the scars as an effort for subsequent regeneration. Sprouting formation is caused by the disturbance in physiological processes, especially the auxin flow. The disturbed phloem system might inhibit the transport of auxin from the tip to the base of the stem, which resulted in the reduction of auxin concentration under the circular incision. This will result in cytokinin synthesis at the stem's base, stimulating sprouting formation [22]. The pure stand of *E. pellita* in this study was larger in diameter when compared to the other two stands. It is suspected that the difference in diameter is due to differences in genetic factors and the activity of endogenous hormones, i.e., auxins and cytokinins. The hybrid stand was younger than both pure stands but taller trees, which indicated that the auxin synthesis was still dominated in the meristematic tissue. Meanwhile, in five years older pure stands, the apical growth had been reduced and replaced by lateral growth due to cytokinin activity, which caused the larger diameter.

In addition to tree size, the success of sprouting is also related to the thickness of the bark connected to the secondary phloem. The thicker bark (due to age or genetics) is difficult to penetrate by dormant buds on the cambium, especially when the connective tissue between the dormant buds and the pith has been damaged. The thinner the bark, the easier the cracking process will be to emerge the secondary periderm and phloem [23]. In this study, the bark of hybrid was thicker than both the pure eucalypts. A similar result was reported by [25], which found that the bark of pure *E. pellita* and *E. brassiana* is furrowed but relatively shallow (1-2 cm in *E. pellita* and 0.5 cm in *E. brassiana*) and easily peeled. However, the hybrid's bark is less-peeled and thickened, with more than 3 cm deeper furrow (Figure 4).
3.3. Estimating the rooting ability

Different species and concentrations of IBA had a significant effect on the cutting survival (Figure 5a). Eight weeks after being treated with 100 ppm IBA, cuttings of *E. pellita* performed the highest rate of survival (96% to 100%), followed by *E. brassiana* (52% to 66.67%), while the hybrid was the lowest in survival (4% to 8.33%), respectively. Application of both 1000 ppm and 4000 ppm IBA has resulted in a very low level of survival (ranged from 0% to 1% in *E. brassiana*, 1% to 5% in *E. pellita*, and 0% in the hybrid, respectively).

Similarly, the species and concentration of IBA significantly affect the formation of new leaves (Figure 5b). Eight weeks after being treated with 100 ppm IBA, cuttings of *E. pellita* formed the most abundant leaves (14 to 16 leaves), followed by *E. brassiana* (7 leaves) and the hybrid (3 to 4 leaves), respectively. Application of 1000 ppm IBA resulted in a very limited number of leaves (ranged from 5 to 6 leaves in *E. pellita*, 0 to 2 in *E. brassiana*, and 0 in the hybrid, respectively). Application of 4000 ppm IBA only produced 2 to 4 leaves in *E. pellita* and failed to form leaves in both *E. brassiana* and hybrid cuttings. Meanwhile, two types of media did not significantly affect both the cutting survival and leaf formation.

Figure 4. The sproutings and the bark characteristics in eucalypts: (a) the abundant sproutings (left) and the furrowed but relatively shallow (1-2 cm) and easily peeled bark in *E. pellita* (right); (b) the moderate level of sproutings (left) and the shallow (0.5 cm) and easily peeled bark in *E. brassiana* (right); and (c) the fewer sproutings (left) and the less-peeled and thickened (more than 3 cm of deeper furrow) bark in the hybrid of *E. pellita x E. brassiana* (right).

Figure 5. The rooting ability of *E. brassiana*, *E. pellita* and their hybrids treated with three levels of IBA (H1: 100 ppm, H2: 1000 ppm, and H3: 4000 ppm) and two types of media (M1: sand, rice husk charcoal and cocopeat (2:2:1), and M2: sand, topsoil and dung-fertilizer (2:2:1)): (a) the cuttings survival at eight weeks (%) and (b) the number of new leaves per cutting.
In this study, cuttings obtained from pure species performed higher survival compared to the hybrids. A similar result was observed with *E. camaldulensis* in India, in which pure species survived more (26.67% to 42.33%) than its hybrid (18.67% to 25.67%) [5]. However, compared to their study, the survival rate was somehow higher in this study, particularly for the pure species (ranged from 96% to 100% in *E. pellita* and 52% to 66.67% in *E. brassiana*, respectively).

This study revealed that applying only a low level of IBA might increase the success of cuttings in eucalypts. At the same time, the excess of hormones might result in mortality due to the toxic effects. Many studies have also proven similar results that applying only a low level of auxin-based hormones significantly increased rooting in cuttings. In India, the best results (60%) were achieved in Casuarina cuttings after being treated with only 50 ppm IBA for three hours; while in the hybrid of *E. camaldulensis* × *E. tereticornis*, application of 100 ppm IBA for ten minutes gave a 95% of survival [16]. In China, a 300 ppm IBA for 15 minutes gave the best result for *E. grandis* × *E. urophylla* cuttings [12]. Only 100 ppm of Rootone-F is sufficient for *S. album*, *Acacia* sp. and *Shorea* sp. cuttings in Indonesia [17]. However, other studies reported a higher level of IBA to achieve the best result in eucalypt cuttings. In *E. camaldulensis* planted in Iran, the greatest root dry weight (0.52 gr) was achieved in 500 ppm IBA, but the highest survival (78.9%) has resulted from 2000 ppm IBA application [17]. Another study in *E. camaldulensis* and its hybrid in India revealed a 2000 to 4000 ppm IBA needed for the best cuttings [5].

In this study, two types of media (the mixture of sand, rice husk charcoal and cocopeat, and the mixture of sand, topsoil and dung-fertilizer) showed no differences in the success of cuttings. Many studies reported a wide variety of media that are used for eucalypts cuttings. In many South and East African countries, eucalypt cuttings were planted in various cheaper and mostly available media, such as river sand, clay, topsoil, sawdust, cocopeat, and rice husk [4]. In India, vermiculite, sollite, peat, and sand are the most suitable media. A mixture of 40% vermiculite, 20% sultite and 40% sand, along with 4000 ppm IBA, significantly increase the sprouting and rooting success of cuttings in *E. camaldulensis* and its hybrid [5]. In Spain, sometimes cuttings are made without hormone application, with coconut fiber and peat as a media, under a shade house with air humidity control [2]. Bio-fertilizer might also increase rooting on eucalypt cuttings. The best result for *E. camaldulensis* was achieved by applying bio-fertilizer at half of the total media, along with 500 to 2000 ppm IBA [17].

### 4. Conclusion

Results selected a total of 53 plus tree candidates (29 of *E. pellita*, 12 of *E. brassiana*, and 12 of hybrid). Qualitative and quantitative scores are similar for *E. pellita* and *E. brassiana*, while the hybrid is scored somehow lower, particularly in quantitative characters. The best four in *E. pellita* are P96 (205), P618 (222), P451 (234), and P468 (202), while in *E. brassiana* are B105, B77, B107, B64. In hybrid stand, the B3P5, B3P1, B4P1, B5P1 hybrids performed the best phenotype. The B3 (the parent trees number 3 of *E. brassiana*) are the best for female parents, while P1 (the parent trees number 1 of *E. pellita*) are the best for male parents.

*E. pellita* is the best in sprouting ability (100% survival; 41-60 shoot trees, 127-161 cm shoot length, 0.53-0.57 cm shoot diameter, and 194-252 leaves shoot). The hybrid observed the opposite result, producing the lowest shoot number per tree, shoot length, shoot diameter, and leaves per shoot.

Different species and concentrations of Indole Butyric Acid (IBA) significantly affected the cutting survival and the formation of new leaves. Eight weeks after being treated with 100 ppm IBA, cuttings of *E. pellita* gained the highest survival and leaves production (96%-100%; 14-16 leaves), followed by *E. brassiana* (52%-66.67%; 7 leaves) and the hybrid (4% to 8.33%; 3-4 leaves). Application of both 1000 ppm and 4000 ppm IBA has resulted in a very low level of survival (ranged from 0% to 1% in *E. brassiana*, 1% to 5% in *E. pellita*, and 0% in the hybrid, respectively). Meanwhile, two types of media did not significantly affect both the cutting survival and leaf formation.

These results may contribute to arranging better strategies for mass production of selected eucalypts. Further studies are recommended to find the most effective techniques for mass vegetative...
propagation, i.e., by cuttings and graftings, to copy the best genotypes of plus trees. The copies can be used as genetic materials to establish hedge orchards for large-scale propagation.

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