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# Selection of Plus Tree Based on Growth Performance and Fiber Morphology Characteristics as Improved Sources for Propagation of *Eucalyptus camaldulensis*

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## Abstract

**One of the most successful techniques in planting trees is tree improvement in which trees with high qualities are selected for mass plantation. This study seeks to identify good properties of *Eucalyptus camaldulensis* through selective phases. Sixty *Eucalyptus camaldulensis* trees (30 ten-year-old and 30 five-year-old) were randomly selected through stratified sampling from two plantation sites in Kurdistan region, North of Iraq. The trees were examined for fiber morphology and quality parameters such as height, number of branches, diameter and straightness. In the first phase of property selection, sixteen trees with high rank in growth properties and fiber morphology were selected. In the final phase of selection, the selected trees were re-examined according to the number of properties and fiber morphology features and seven trees with the highest number of good parameters were chosen. The 7 selected trees had higher qualities in growth characteristics and fiber morphology compared with the other trees in the sample. This article reports on a selection method for *E. camaldulensis* trees through tree improvement techniques. The results of the study indicates that high genotype qualities were identified among both 5- and 10-year-old *E. camaldulensis* trees as the final selection consisted of three 5-year-old trees and four 10-year-old trees.**

## Keywords

***Eucalyptus camaldulensis*; Tree Improvement; Growth Characteristics; Fiber Morphology**

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## 1. Introduction

The River Red Gum (*Eucalyptus camaldulensis*) which is an indigenous tree species to Australia plays an important role in paper production industry for different countries all over the world [1]-[3]. This type of tree is cultivated for various purposes such as timber and charcoal production. It has versatile uses and it is an important forest product. It has some unique features as it is a fast growing tree and produces most durable heaviest and hardest wood [4]. According to Global Eucalyptus Map Website (2009), there are more than 20 million ha of Eucalyptus plantation all over the world (India: 3,942,600 h; Brazil: 3,751,857 h; China: 2,609,700 h; Australia: 875,000 h) [4]. *E. camaldulensis* is an economically important tree due to its significant uses. The wood of Red gum has been used in heavy contraction, such as, flooring, fencing, railway sleepers, framing, plywood and wood turning, pulp and paper, fire wood, veneer manufacture and charcoal production [1]. It has versatile uses and it is an important forest product. It has some unique features as it is a fast growing tree and produces most durable heaviest and hardest wood [5]. Furthermore, this tree grows well in various soils and climates [6]. *E. camaldulensis* is cultivated for pulp and paper production in Iraq. It has also been planted as ornamental tree for landscaping and agroforestry purposes [1]-[7].

*E. camaldulensis* has been largely planted in vast irrigated plantations in the North of Iraq. It adjusts well to different types of soil and various climatic modifications. It is generally suggested that rotation cycle for *E. camaldulensis* is 10 to 11 years. At this age, the average size of diameter ranges from 25 to 30 cm. 10- or 11-year-old *E. camaldulensis* has the highest possible wood quantity that is required by pulp market [7]. Moreover, tree improvement has been recognized as a helpful and effective technique for farmers to develop their woodlands farms through selecting the most appropriate and highest genotypes. Thus, this study was conducted to examine the plus tree selection for *E. camaldulensis* in Iraq.

## 2. Materials and Method

### 2.1. Description of Study Site

*Eucalyptus camaldulensis* were selected and screened from 10-year-old and 5-year-old tree plantations of Khabat and Pirde, located in Erbil, North of Iraq. Khabat plantation is situated on a sandy area in the West of Erbil (36˚15N, 43˚38E) with temperatures ranging between 4˚C to 41˚C, and an annual precipitation of 385 - 455 mm/year. Pirde is located on a semi flat land in the South of Erbil (35˚06N, 44˚08E) with a temperature of 9˚C-45˚C and has annual precipitation about 319 - 402 mm/year.

### 2.2. Tree Selection Procedure

There are two large *E. camaldulensis* plantations in Kurdistan, Iraq. In the biggest plantation site, Khabat, there were 5000 trees from which almost 2100 trees were 5-year-old and the rest are 10-year-old. In Pirde, the second biggest plantation, there were 22005 of 5-year-old and 1850 of 10-year-old trees. Each plantation is located by a river from which it is irrigated. The area of plantation was 5 ha (2.6 ha 5-year-old and 2.4 ha 10-year-old), and 4.7 ha (2.7 ha 5-year-old and 2 ha 10-year-old) for Khabat and Pirde respectively. The trees were planted at a space of 3 m × 4 m. A sample of 60 trees was selected from two *E. camaldulensis* plantations through stratified sampling on July 2012. From each plantation, 15 trees from each age group were selected for this study. The selected trees were named based on the age and the site. Kh is referred to Khabat plantation, and Pr is used for Pirde plantation. Numbering of 5 and 10 were used for the age it represents, and X refers to tree numbering (1-15). The same procedure was used for naming the other trees in the sample. The sample was composed of four sub-groups, and there were fifteen trees in each sub-group.

In this study, both qualitative and quantitative characteristics were used as criteria for plus tree selection. The trees in each sub-group were carefully examined and rated in quantitative properties such as height, diameter, crown height, and qualitative properties such as tree shape, branching habits (size and angle) and number of knots. Each tree was given a score ranging from 1 to 15 for a specific property, where 15 indicates the highest rank while 1 shows that the tree has the lowest quality in a specific characteristic compared with the other 14 trees in the sub-group. Each growth characteristic was evaluated separately for each tree.

### 2.3. Determination of Fiber Dimensions and Derived Values

Since quality of paper depends on fiber morphology characteristics, thus fiber dimensions such as fiber length,

fiber diameter, cell wall thickness, lumen diameter were separated (Fiberization) and measured according to the Technical Association of Pulp and Paper Industry (TAPPI) standard T233-Su-64 [8]. Derived values such as flexibility, slenderness ratio and Runkel ratio were also calculated using fiber dimensions through these equations:

1) $$\text{Flexibility} = \frac{\text{fiber lumen diameter}}{\text{fiber diameter}}$$

2) $$\text{Slenderness Ratio} = \frac{\text{fiber length}}{\text{fiber diameter}}$$

3) $$\text{Runkel Ratio} = \frac{2 \times \text{fiber cell wall thickness}}{\text{fiber lumen diameter}}$$

Wood samples were split separately into a match stick size of 2 mm in width and 10 - 20 in length, and then placed in the boiling tubes. 25 ml of distilled water was added plus 1.5 g of Sodium chlorite and 2 - 3 drops of Acetic acid for each tube. Then they were boiled in water bath placed under fume hood at 70˚C for about 24 hours. When fibers were turned into silver color, they were washed with distilled water. After washing fibers, they were separated by shaking. The macerated fiber suspensions were stained in 2 - 3 drop of 1% safranin-O for 30 minutes and placed on a slide and covered with a cover slip.

All samples were viewed under Leica Image analyzer (Leitz DMRB). A total of 30 randomly chosen fibers were measured from each slide. There are two treatments: plantation site and tree age. The qualities of Khabat trees were compared with those from Pirde. In addition, the two age groups were compared for the qualities and properties. Scores to these characteristics were added and were later ranked. After data analyzing for the growth parameter (quantitative and qualitative) and fiber morphology, the trees were ranked based on cumulative characteristics; (growth parameter + fiber morphology rank)/2.

### 2.4. Data Analysis

For data analysis, independent T-test was used to analyze data, first, 5-year-old trees from (Kh) and (Pr) were compared. Then, 10-year-old trees from (Kh) and (Pr) were compared (at 5% level of probability).

## 3. Results and Discussions

Growth characteristics of the *E. camaldulensis* trees selected through plus tree procedures is presented in **Table 1**. The diameter growth and height of the selected tree were compared with those reported on the same species of the age 6-year [9]. The results indicate that height and diameter were 13.66 m and 14.56 cm respectively which were higher than those in [9] study (13.7 m height and 11.2 cm diameter). This is due to better values attributed by those plus trees, whereas the ones that they obtained was based on the overall average growth of 6-year-old *Eucalyptus camaldulensis* in Napa.

The results show that there is no significant difference between two plantations for 5-year-old trees ($p < 0.05$) in growth performance characteristics, while there was a significant difference the Khabat and Pirde plantations for 10-year-old trees in growth parameters(at $p < 0.05$) as shown in **Figure 1**.

The best two trees were chosen based on growth, fiber morphology and cumulative scores, as summarized in **Table 2** Based on the overall growth performance, five trees from Khabat plantation (5Kh-6, 5Kh-8, 10Kh-14 and 10Kh-15) and four trees from Pirde plantation (5Pr-6, 5 Pr -11, 10 Pr -8, 10 Pr -12) were selected.

Besides growth parameters, the mean of fiber morphology characteristics of the selected trees for both age groups in the two plantations are shown in **Figure 2**. Results show no significant difference between the two plantation sites $p < 0.05$ for fiber morphology characteristics. In addition, no significant difference was found between two plantations for both 5-year-old trees and 10-year-old trees in fiber morphology (**Figure 3**). Mean fiber characteristics of both plantations are presented in **Table 3**. All mean fiber characteristics of 5 years old of the both plantation were compared to those mean fiber characteristics of 5 years old of *Leucaena lencocephala* that obtained by [10] (**Table 4**). In fact, the fiber length that obtained from this study was higher than those obtained by [10] for tree *Leucaena lencocephala*. In contrast the runkel ratio of *Leucaena lencocephala* trees were higher than those obtained in this study for *Eucalyptus camaldulensis.*

Oluwadare and Ashimiyu [10] stated that the fiber length and cell-wall thickness have relationship with

**Table 1.** Qualitative and quantitative growth data of plus trees of *Eucalyptus camaldulensis*.

| Growth parameter | Khabat Plantation | | | | Pirde Plantation | | | | Napa Plantation |
|---|---|---|---|---|---|---|---|---|---|
| | 5-year-old tree | | 10-year-old tree | | 5-year-old | | 10-year-old tree | | 6-year-old tree |
| | range | mean | range | mean | range | mean | range | mean | mean |
| Tree height (m) | 11.50 - 15.00 | 13.66 | 14.00 - 20.00 | 16.86 | 11.00 - 16.00 | 13.1 | 15.00 - 19.00 | 17.06 | 13.66 m |
| DBH (cm) | 11.50 - 17.00 | 14.56 | 17.00 - 23.00 | 19.53 | 12.5 - 17.50 | 14.63 | 17.00 - 22.00 | 19.36 | 14.56 cm |
| Crown height (m) | 3.50 - 7.00 | 5.15 | 4.300 - 7.30 | 5.80 | 3.50 - 5.00 | 4.12 | 5.50 - 7.50 | 6.54 | |
| Clear bole (m) | 7.50 - 10.00 | 8.51 | 9.70 - 14.00 | 11.06 | 7.00 - 11.00 | 8.95 | 9.00 - 12.50 | 10.56 | |
| No. of branch | 14 - 27 | 19.8 | 16 - 26 | 21.9 | 12 - 20 | 19.5 | 20 - 25 | 22.40 | |
| No. of knot | 5 - 12 | 8.23 | 7 - 13 | 10.26 | 5 - 9 | 8.7 | 5 - 12 | 7.66 | |

**Table 2.** Superior plus trees based on growth (qualitative and quantitative) fiber morphology, and cumulative scores.

| Location | Age | | | | | |
|---|---|---|---|---|---|---|
| | 5-year-old tree | | | 10-year-old tree | | |
| | Growth (Qualitative and Quantitative) | Fiber Morphology | Cumulative | Growth (Qualitative and Quantitative) | Fiber Morphology | Cumulative |
| Khabat Plantation | 5Kh-6 | 5Kh-10 | 5Kh-7 | 10Kh-14 | 10Kh-3 | 10Kh-3 |
| | 5Kh-8 | 5Kh-14 | 5Kh-8 | 10Kh-15 | 10Kh-7 | 10Kh-15 |
| Pirde Plantation | 5Pr-6 | 5Pr-3 | 5Pr-3 | 10Pr-8 | 10Pr-7 | 10Pr-7 |
| | 5Pr-11 | 5Pr-5 | 5Pr-6 | 10Pr-12 | 10Pr-12 | 10Pr-12 |

*Kh = Khabat; Pr = Pirde.

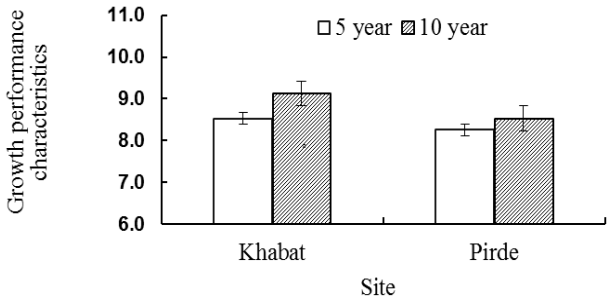


**Figure 1.** Growth performance characteristics of 5- and 10-year-old *Eucalyptus camaldulensis* at Khabat and Pirde plantation sites.

strength properties of the unbeaten pulp of hard woods. In addition, Dharm and Tyagi [11] also found that good quality pulp has a Runkel ratio value of below 1.0 which is a good indicator for pulp production. Normally, fibers with Runkel ratio of below than 1.0 have thin cell wall indicates good strength properties. Runkel ratio is also related to paper conformity and pulp products. Mean Runkel ratios for Khabat trees are below 1, indicating 0.81 and 0.97 for 5- and 10-year-old trees respectively. As for Pirde trees, the mean Runkel ratio is equal to 1 for both age-groups. Fiber analysis shows that the *E. camaldulensis* trees from both plantations have considerable strength and are suitable for good paper production.

Based on the growth, fiber morphology and cumulative scores, the best two trees were identified as summarized in **Table 2**. With regard to growth performance indicators, eight trees were selected at the final stages. The selected trees are 5Kh-6, 5Kh-8 (**Figure 4(a)**), 10Kh-14, 10Kh-15, 5Pr-6, 5Pr-11, 10Pr-8 and 10Pr-12. On the other hand, for fiber morphology properties, 8 trees were selected; they are 5Kh-10, 5Kh-14, 10Kh-3, 10Kh-7, 5Pr-3 (**Figure 4(b)**), 5Pr-5, 10Pr-7 and 10Pr-12. Overall, for both growth and fiber characteristics (cumulative characteristics) 8 trees with the highest properties were identified. The trees with highest cumulative characteristics are 5Kh-7, 5Kh-8, 10Kh-3, 10Kh-15, 5Pr-3, 5Pr-6, 10Pr-7 and 10Pr-12 (**Figure 4(c)**).

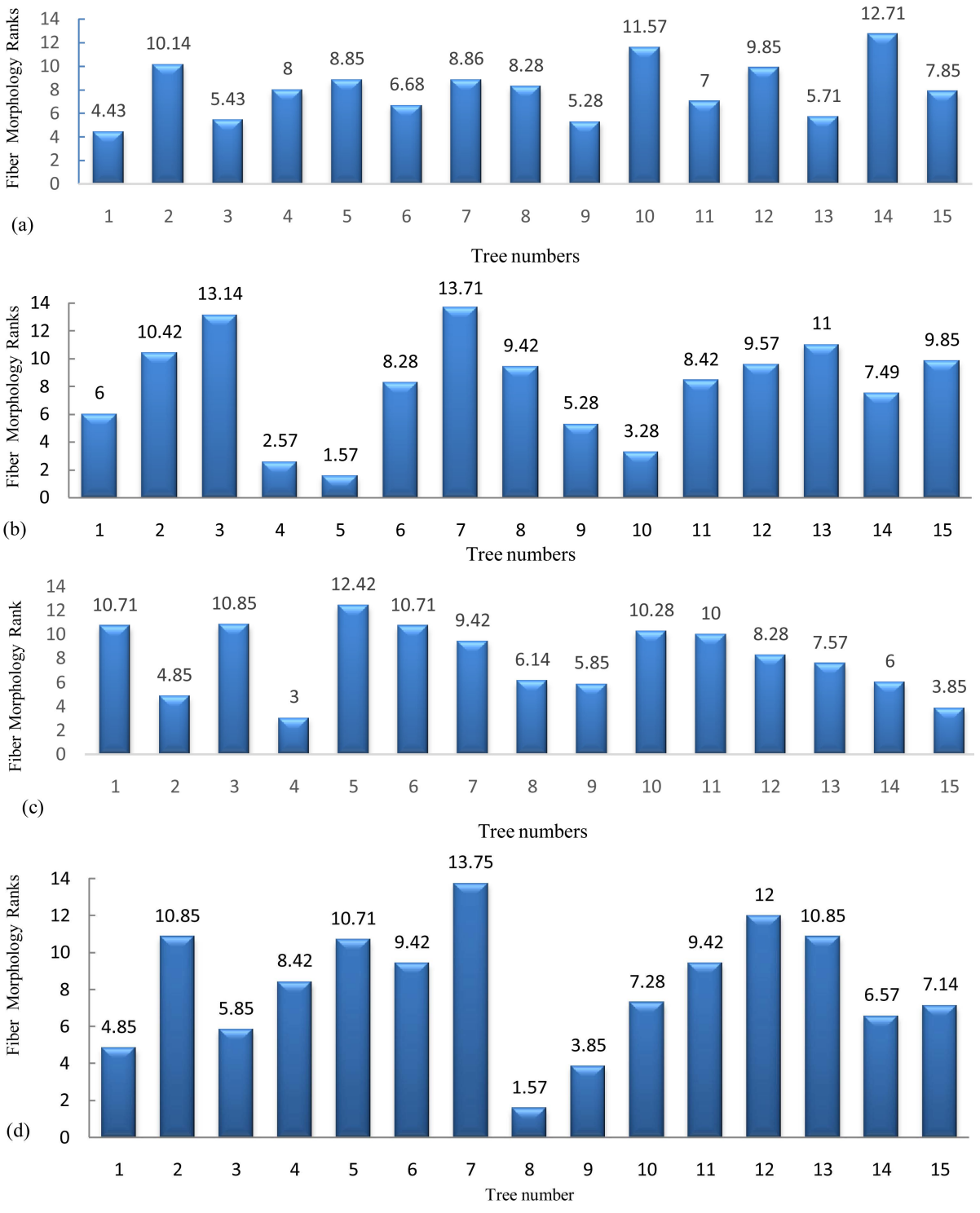


**Figure 2.** Fiber morphology (a) 5-year-old Khabat plantation; (b) 10-year-old Khabat plantation; (c) 5-year-old from Pirde plantation; (d) 10-year-old from Pirde plantation.

## 4. Conclusion

The result of this study showed that the growth performance characteristics of Eucalyptus trees from both plan tations are comparable to those results obtained by [10] and acceptable as sources for propagation. Regarding

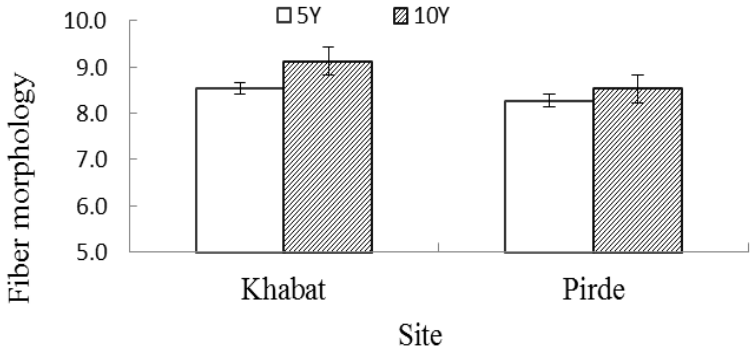


**Figure 3.** Fiber morphology of 5- or 10-year-old *Eucalyptus camaldulensis* at Khabat and Pirde plantation sites.

**Table 3.** Mean fiber characteristics of *Eucalyptus camaldulensis*.

| Fiber dimensions | Khabat Plantation | | Pirde Plantation | |
|---|---|---|---|---|
| | Mean value | | Mean value | |
| | 5-year-old tree | 10-year-old tree | 5-year-old | 10-year-old tree |
| Fiber length (µm) | 679.66 | 682.17 | 655.31 | 680.56 |
| Fiber diameter (µm) | 10.64 | 13.41 | 13.53 | 13.31 |
| lumen diameter(µm) | 5.87 | 6.80 | 6.90 | 6.53 |
| Cell wall thickness(µm) | 2.38 | 3.31 | 3.32 | 3.38 |
| Slenderness ratio | 63.98 | 51.05 | 48.80 | 51.27 |
| Flexibility | 0.55 | 0.50 | 0.51 | 0.49 |
| Runkel ratio | 0.81 | 0.97 | 1.00 | 1.00 |

**Table 4.** Comparing mean fiber characteristics of 5-year-old *Eucalyptus camaldulensis* with 5-year-old *Leucaenalencocephala* that obtained by [10].

| Fiber dimensions | *Eucalyptus camaldulensis* | | *Leucaena lencocephala* |
|---|---|---|---|
| | Mean Value | | Mean Value |
| | Khabat Plantation | Pirde Plantation | |
| Fiber length (µm) | 679.66 | 655.31 | 652.00 |
| Fiber diameter (µm) | 10.64 | 13.53 | 15.67 |
| lumen diameter (µm) | 5.87 | 6.90 | 9.87 |
| Cell wall thickness (µm) | 2.38 | 3.32 | 2.90 |
| Slenderness ratio | 63.98 | 48.80 | 41.61 |
| Flexibility | 0.55 | 0.51 | 0.63 |
| Runkel ratio | 0.81 | 1.00 | 0.59 |

fiber morphology characteristics, there are no significant differences between two groups. Overall, seven trees (four from Pirde and three from Khabat) were selected as sources for propagation of *Eucalyptus camaldulensis* for paper production. Tree 10Pr-12 is the best source based on overall performances.

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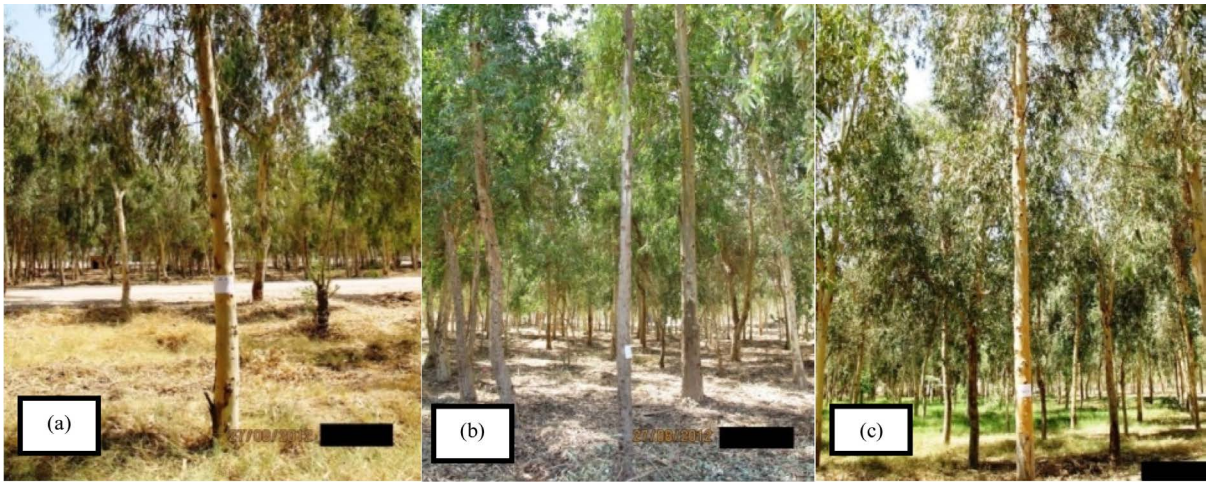


**Figure 4.** Examples of superior plus trees as sources for propagation purposes: (a) Tree no. 5Kh-8 based on the growth parameter; (b) Tree no. 5Pr-3 based on fiber morphology characteristic; (c) Tree no. 10Pr-12 based on cumulative scores (fiber morphology and growth parameter). Scale 1 m.

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