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# Vegetative propagation technologies using stem and root cuttings of *Paulownia* (*P. fortunei* and *P. elongata*) tree species for mass production

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**Key words:** *Paulownia*, Indole-3-butyric acid, Root and stem cuttings, Sprouting and rooting potentials, Vegetative propagation

## Abstract

*Paulownia* is a multipurpose tree with high-quality wood features including machining qualities, rot resistance, fast growth, a good tree form, high yield, light wood weight and good potential for plantation and agroforestry. In 2012, *Paulownia* was introduced into Ghana under the FC/Industry plantations project for field trials at Asenanyo and Pra-Anum Forest Reserves. Recent field assessment depicted their inability to produce viable seeds for propagation. Thus, vegetative propagation techniques were investigated to possibly produce high-quality planting materials for large scale *Paulownia* (*P. elongata* and *P. fortunei*) plantations. Root and stem plant materials were collected from Pra-Anum Forest Reserve. They were treated with 0.0% (control), 0.1%, and 0.3% Indole-3-Butyric Acid (IBA) levels and planted in polyethylene bags filled with loamy soils and kept under shade. Root cuttings were planted horizontally in a 2x3 factorial design with 10 cuttings per treatment replicated 4 times. Stem (bi-nodal leafless hardwood) cuttings were vertically planted in 2x4 factorial design, 10 cuttings per treatment at 3 replications. A completely randomized design (CRD) was used. The root cuttings of both species survived irrespective of IBA levels. A significant variation ($P \leq 0.05$) was observed in the survival rate (over 75%), sprouting and rooting abilities. The stem cuttings were not successful, though, they developed shoots and leaves at the initial stages. In conclusion, vegetative propagation of *Paulownia* particularly, root cutting is possible for the multiplication of planting materials for plantation establishment. It is ill-advised to use lignified brown stem/ hardwood cuttings for the propagation of *Paulownia*.

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## Introduction

*Paulownia* tree belongs to the monogenetic family Paulowniaceae of the Scrophulariaceae family. It is a deciduous tree that originated from East Asia. Its wood has a high economic premium due to the timber export value of billions of dollars. *Paulownia* tree is grown to serve numerous purposes ranging from reforestation and aesthetic purposes to the environmental protection due to its fast growth ability and beautiful large leaves, mauve flowers and aroma. The ability of the tree to grow rapidly makes it a favorable economic choice to harness large quantities of biomass (60-80ton/ha) within a short frame of time (Danciu *et al.*, 2016). Also, the tree can be planted for soil reclamation, green manuring, fodder, herbal medicine and as a windbreak (Johnson, 2000). The tree is propagated by both sexual and asexual means. There are many merits associated with vegetative propagation of *Paulownia* making it the most effective means over seedling production. Seeds of *Paulownia* exhibit slow germination growth and slower growth of seedlings which is not the case of planting materials raised from root or shoot cuttings or rooted shoots from tissue culture (Bergmann and Moon, 1997). *Paulownia* trees have multiple uses including its application in a short-rotation woody crop plant, afforestation, mine site reclamation, managed plantations and intercropping systems (Bergmann and Moon, 1997, Wang and Shogren, 1992, Zhu *et al.*, 1986, Carpenter, 1977). The leaves of *Paulownia* are also good for fertilizer and animal feeds, and their flowers used in honey production and wood for solid wood products (Zhu *et al.*, 1986). *Paulownia*, can be used for the production of energy, wooden building materials, and paper pulp (Bergmann and Moon, 1997).

As an introduced tree species into Ghana planted at Asenanyo and Pra-Anum Forest Reserves, there was a need to increase the production level to cover a large area of land to reap the tremendous environmental and economic benefits it presents. The premier trial when the tree species was introduced into Ghana was carried out through sexual propagation. Therefore, there was a need to find the best alternative propagation methods to increase the number of planting materials and subsequently be used in the expansion of the area of cultivation. On that note, this purpose could only be realised through the use of vegetative propagation techniques. The experiment was to use stem and root cutting propagation technologies to ensure success in the rooting and sprouting potentials of *Paulownia* tree (*P. elongata* and *P. fortunei*) species in Ghana. The number of *Paulownia* planting materials would be increased for possible large-scale production in Ghana. Also, *Paulownia* clones of similar and high genetic traits would be maintained coupled with early maturity rate. An alternative mass macropropagation protocol for the tree species in Ghana was accomplished. The main objective was to determine the effective propagation of the two *P. elongata* and *P. fortunei* species through root cuttings and stem (bi-nodal leafless hardwood) cuttings. The specific objectives included determining the survival, sprouting and rooting abilities of root cuttings between the two *Paulownia* species as influenced by IBA levels; and the survivability, sprouting and rooting potentials of stem cuttings between the two *Paulownia* species as influenced by IBA combinations.

## Materials and methods

*Source of Plant Materials*

The plant materials comprising the stem and root parts of the two *Paulownia* tree species (*P. elongata* and *P. fortunei*) were collected from Pra-Anum Forest Reserve for the setting up of the experiment at the Council for Scientific and Industrial Research, Forestry Research Institute of Ghana (CSIR-FORIG) nursery. Pra-Anum Forest Reserve (6˚16' N, 1˚12' W) is in the South-East sub-type of Moist Semi-Deciduous ecological forest zone in Ghana (Hall and Swaine, 1981). The forest reserve covers an area of about 12,332 ha. Since 1954, Pra-Anum forest reserve has served as a timber production area and silvicultural research station (FIP, 1989). The area has a total mean annual rainfall of between 980 mm and 1,706mm, and temperature of 23.0˚C and 27.5˚C. It has a deeply weathered soil type consisting of forest oxysolochrosol intergrades (Brammer, 1962).

*Study Area: CSIR-FORIG Nursery*

CSIR-Forestry Research Institute of Ghana Nursery where the experiment was carried out is situated at Fumesua in the Ejisu Municipality of Ashanti Region. The area lies within Latitudes 1˚15′ N and 1˚45′ N, and Longitude 6˚15′ W and 7˚00′ W. It has bi-modal rainfall pattern with an average annual rainfall of 900mm–1,500 mm per year. The mean annual temperatures range between 25˚C and 32˚C with a moderate relative humidity but quite high in the rainy season. The area lies in the Moist Semi-Deciduous forest zone of Ghana (GSS, 2014).

*Collection of the Plant Materials*

The brown stem (bi-nodal leafless hardwood) parts of both *Paulownia* species were collected by cutting with sharp and sterilised secateurs from their parent stocks and all the leaves excised to obtain the stem cuttings. A mattock was used to dig and expose the root systems of the parent stocks of both *Paulownia* trees. Thereafter, the exposed roots were harvested using sharp cutlasses. Both stem and root parts collected were separately cleaned, put in zip-lock bags and film of water misted on them using a mist sprayer. They were then kept and stored in an ice chest before transporting them to CSIR-FORIG nursery to set up the experiment within five hours after harvesting.

*Experimental Design*

*Root Cutting Propagation of Paulownia Tree Species*

Roots of both *Paulownia elongata* and *fortunei* were cut at a uniform length of 10cm long. The root cuttings were cut at an approximate diameter between 7 and 14mm. All the root cuttings were treated with a fungicide solution to curb fungi attacks. They were then subjected to two levels of Indole-3-Butyric Acid (IBA) treatments; 0.1%, 0.3% and no chemical application (control treatment). A root inducing substance, "Hormodin® a registered trademark of OHP, Inc., Mainland-Canada" with IBA as the active ingredient was used. The treated root cuttings were horizontally planted in polyethylene bags filled with loamy soils and kept under homogenous shade. Misting of water on the root cuttings was done twice daily to keep moderate moisture level. Subsequently, the root cuttings were used in two (2) factorial experiments (2 species-*P. elongata* & *P. fortunei* x 3 IBA levels) with 10 root cuttings per treatment. A completely randomized design (CRD) with four (4) replications was used. Root cuttings were deemed sprouted when new shoots emerged. Parameters taken into consideration were cuttings survived, cuttings sprouted, number of shoots developed, number of leaves, length of developed shoots, number of roots and the length of roots at 48 days after planting.

*Bi-Nodal Hardwood (Stem) Cutting Propagation of Paulownia Tree Species*

*Paulownia elongata* and *fortunei* tree species were used as the parent stock plants for the stem cutting experiment. Bi-nodal leafless hardwood cuttings of both species were cut at an equal length of 10cm long and then treated with a fungicide solution. The proximal ends of the stem cuttings were dipped in rooting powder of 0.0% (control treatment), 0.1% and 0.3% IBA concentrations and the excesses shook off. Thereafter, the auxin treated stem cuttings were inserted vertically with the distal ends upwards in polyethylene bags filled with loamy soils and kept under homogenous shade. The management of the stem cuttings followed the same process as described earlier (Output 1). The stem cuttings were used in two (2) factorial experiments (2 species x 3 IBA levels) with 10 cuttings per treatment. A completely randomized design with 3 replications was used. A stem cutting was considered rooted when the longest root was ≥ 1cm. Parameters assessed were as in Output 1.

*Data analysis*

Data were subjected to one-way analysis of variance (ANOVA) using Origin® 9.1 Data Analysis and Graphing Software. Fisher's least significant difference (LSD) procedure was used for the separation of means where appropriate at 5% ($\alpha$ = 0.05). The means were calculated and bar graphs used for the comparison of the survival percentage between the two *Paulownia* species and the IBA treatments on the survival of *Paulownia* root cutting propagation.

To compare the period for sprouting, means were used to calculate the percentage of cuttings sprouted and used to develop bar graphs. The mean for the number of shoots, length of shoots/sprouts and number of leaves produced by root and stem cuttings of *Paulownia* tree species as affected by IBA application were calculated and presented in tables. To compare the number of roots and length of roots produced by root cuttings between the *Paulownia* tree species as affected by IBA application, means were calculated and presented in tables. Means with the same letter superscript are not significantly different at 5% level (P≤0.05). Bar graphs were used to present the percentage of root and stem cuttings of the two *Paulownia* species sprouted some days after planting.

## Results

*Root Cutting Propagation of Paulownia Species*

The survival rate of root cuttings of *P. elongata* was higher than *P. fortunei* (Fig. 1). There was a significant difference (P≤0.05) in the per cent survival of *P. elongata* than that of *P. fortunei*, even though the difference in the survival rate was marginal. Close to 80% survival rate was recorded by both *Paulownia* species (Fig. 1). The root cuttings of both *P. elongata* and *P. fortunei* started to sprout 14 days after propagation (Fig. 2). They continued to exhibit sprouting potentials till the 29th day after planting when the decline was observed. The highest sprouting abilities of both *P. elongata* and *P. fortunei* was between 15th and 29th days of planting with each of them producing over 70% sprouting potentials (Fig. 2). Development of shoots/sprouts ceased after 48th day of planting, thus no new sprout was observed for both species.

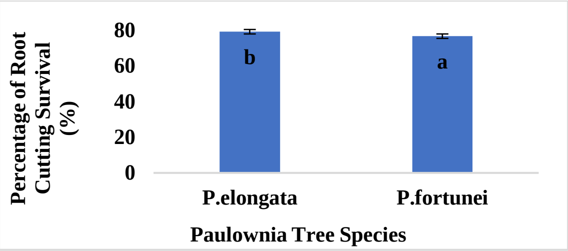


**Fig. 1.** The percentage of survival of root cuttings between *P. elongata* and *P. fortunei* species.

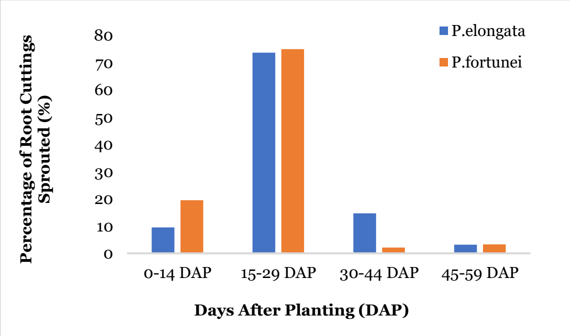


**Fig. 2.** The percentage of root cuttings of *Paulownia* species sprouted days after planting.

A significant difference (P≤0.05) was observed in the percentage of root cuttings survival between the two *Paulownia* species as influenced by the application of IBA levels (Fig. 3). However, 0.1% IBA treatment produced the highest survival rate (92.5%) of root cuttings of *P. elongata*, followed by 0.3% IBA and control treatments. In contrast, the highest survival rate (85.0%) of root cuttings for P. fortunei was exhibited by the control treatment, followed by 0.1% and 0.3% IBA treatments (Fig. 3). The levels of IBA showed no significant variation (P≤0.05) in the number of shoots/sprouts produced by both tree species (Tab. 1). However, for *P. elongata*, the control and 0.3% IBA recorded the same mean number of sprouts of approximately two (~2) whilst 0.1% IBA recording one (~1) sprout per root cuttings (Tab. 1). Although, in the case of *P. fortunei*, the control treatment out-performed the two IBA levels, no significant difference (P≤0.05) was found among the treatments. All the treatments produced an equivalent of two (~2) sprouts per *P. fortunei* tree species on the average (Tab. 1).

**Table 1.** Mean number of shoots, mean shoot length and mean number of leaves produced by root cuttings of *Paulownia* tree species as affected by IBA application.

| *Paulownia* Species | Treatments | Mean Shoot Number | Mean Shoot Length (cm) | Mean Leaf Number |
|---|---|---|---|---|
| *P. elongata* | Control | $1.50^a±0.21$ | $10.20^a±1.50$ | $4.13^a±2.11$ |
| | 0.1% IBA | $1.10^a±0.10$ | $7.30^a±0.92$ | $3.70^a±1.27$ |
| | 0.3% IBA | $1.50^a±0.20$ | $11.10^a±0.87$ | $5.34^a±0.47$ |
| *P. fortunei* | Control | $1.80^a±0.11$ | $10.44^a±2.65$ | $7.21^a±0.42$ |
| | 0.1% IBA | $1.60^a±0.13$ | $7.64^a±0.60$ | $7.40^a±0.21$ |
| | 0.3% IBA | $1.60^a±0.26$ | $9.00^a±0.57$ | $8.65^a±1.14$ |

Means with the same letter superscript are not significantly different at 5% level.

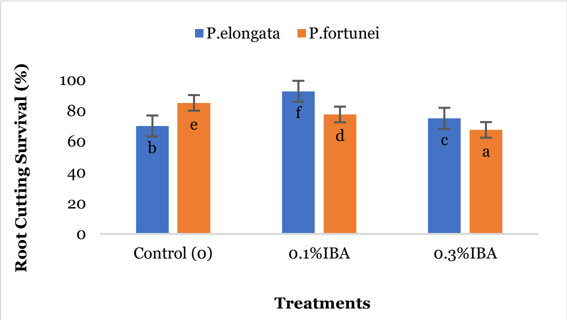


**Fig. 3.** The percentage of survival of root cuttings between *P. elongata* and *P. fortunei* species influenced by IBA levels.

The treatments did not show any significant variation (P≤0.05) between the two *Paulownia* tree species in the mean length of shoots/sprouts. For *P. fortunei*, no IBA application (control) recorded the longest mean length of sprouts of 10.44cm followed by 0.3% IBA (9.00cm) and 0.1% IBA (7.64cm). The mean length of sprouts produced by *P. elongata*, 0.3% IBA treatment recorded 11.10cm followed by the control treatment (10.20cm) and then 0.1% IBA (7.30cm) (Tab. 1). Levels of IBA did not significantly (P≤0.05) affect the production of *Paulownia* leaves. On the average, 0.3% IBA application on *P. elongata* produced the highest number of leaves (5.34) followed by control (4.13) and then 0.1% IBA (3.70). Additionally, 0.3% IBA produced the highest leaf number (8.65) of *P. fortunei* followed by 0.1% IBA (7.4) and control (7.21) (Tab. 1). There was no significant variation (P≤0.05) in the number of roots produced by both tree species (Tab. 2). The control treatment recorded the highest number of roots from *P. elongata* which was followed by 0.3% IBA (2.3) and then 0.1% IBA (1.13) (Tab. 2).

**Table 2.** Mean number of roots and mean root length produced by root cuttings of *Paulownia* tree species as affected by IBA application.

| *Paulownia* Species | Treatments | Mean Root Number | Mean Root Length (cm) |
|---|---|---|---|
| *P. elongata* | Control | $3.10^a±0.70$ | $2.70^a±0.28$ |
| | 0.1% IBA | $1.13^a±0.52$ | $1.00^a±0.25$ |
| | 0.3% IBA | $2.31^a±0.34$ | $2.72^a±1.18$ |
| *P. fortunei* | Control | $2.30^a±0.93$ | $2.20^a±0.76$ |
| | 0.1% IBA | $2.40^a±0.22$ | $1.60^a±0.32$ |
| | 0.3% IBA | $4.00^a±0.50$ | $3.20^a±0.74$ |

Means with the same letter superscript are not significantly different at 5% level.

The 0.3% IBA treatment was higher in the development of roots of *P. fortunei* compared with 2.40 and 2.30 in 0.1% IBA and control treatment respectively (Tab. 2). In terms of the effect of IBA on root length, the two treatments did not show a significant difference (P≤0.05) with the control treatment. The 0.3% IBA treatment recorded the longest root length (2.72cm) of *P. elongata* compared to the control (2.70cm) and 0.1% IBA (1.00cm) treatments (P≤0.05) (Fig. 3 & Tab. 2 ). Again, the 0.1% IBA treatment recorded the shortest root length of *P. fortunei* root cuttings. However, the 0.3% IBA treatment produced the longest root length (3.20cm) followed by the control (2.20cm) (Tab. 2). The number of shoots produced by *P. fortunei* was higher than the other species (Tab. 3). Apart from mean shoot number where there was a significant variation (P≤0.05) between *P. elongata* and *P. fortunei*, no significant difference (P≤0.05) was shown in the shoot length, leaf number, root number and root length (Tab. 3).

**Table 3.** Difference in mean shoot number, shoot length, leaf number, root number and root length of root cuttings between *P. elongata* and *P. fortunei* tree species.

| *Paulownia* Species | Mean Shoot Number | Mean Shoot Length (cm) | Mean Leaf Number | Mean Root Number | Mean Root Length (cm) |
|---|---|---|---|---|---|
| *P. elongata* | $1.34^a±$ 0.10 | $9.53^a±$ 0.77 | $4.40^a±$ 0.78 | $2.20^a±$ 0.37 | $2.04^a±$ 0.46 |
| *P. fortunei* | $1.63^b±$ 0.09 | $9.00^a±$ 0.90 | $7.74^a±$ 0.42 | $3.00^a±$ 0.40 | $2.32^a±$ 0.38 |

Means with the same letter superscript are not significantly different at 5% level.

*Stem Cutting Propagation of Paulownia Tree Species*

There was a significant variation (P≤0.05) in the initial survival rate of stem cuttings between *P. elongata* and *P. fortunei* (Fig. 6). The *P. elongata* recorded higher initial survival rate of 98.87 % than *P. fortunei* (96.67 %). Although the difference was marginal, there was a significant difference (P≤0.05) between *P. elongata* and *P. fortunei* (Fig. 6). In the early first six days of planting, the stem cuttings began to develop shoots/sprouts. The highest percentage of stem cutting sprouts was seen between the $7^{th}$ and $14^{th}$ days of planting with over 78.41% of *P. elongata* and 63.22% of *P. fortunei* species showing sprout potentials (Fig. 7).

In the first six (6) days of planting, 16.00 % of *P. elongata* and 23.00 % of *P. fortunei* stem cuttings sprouted. The sprouting potentials of both species after 14th day of planting started declining to indicate that majority had already sprouted in the early 2 weeks of planting (Fig. 7).

After 21st and 27th day of planting, no new development of shoots/sprouts was recorded for *P. elongata* and *P. fortunei* respectively. No significant difference (P≤0.05) was shown in the number of sprouts produced by the two species among the treatments (Fig. 4 & Tab. 4). The 0.1%IBA level on *P. elongata* recorded the highest performance in shoot number (1.50), sprout/shoot length (3.00cm) and leaf number (4.78) followed by the control and then 0.3% IBA treatments (Tab. 4).

Though, there was no significant difference (P≤0.05), 0.1% IBA treatment except with the length of sprouts/shoots, recorded the highest performance in sprout/shoot number and leaf number of *P. fortunei* tree species. This was followed by the control treatment (Tab. 4). There was no significant difference (P≤0.05) in all the parameters between the two *Paulownia* species. Except for the number of shoots where *P. elongata* performed higher than the other species, *P. fortunei* did better in shoot length and leaf number (Tab. 5).

**Table 4.** Mean number of shoots, mean shoot length and mean number of leaves produced by stem cuttings of *Paulownia* species as affected by IBA application.

| *Paulownia* Species | Treatments | Mean Shoot Number | Mean Shoot Length (cm) | Mean Leaf Number |
|---|---|---|---|---|
| *P. elongata* | Control | $1.42^a\pm$ 0.22 | $2.50^a\pm$ 1.26 | $4.42^a\pm$ 0.87 |
| | 0.1% IBA | $1.50^a\pm$ 0.30 | $3.00^a\pm$ 1.05 | $4.78^a\pm$ 1.49 |
| | 0.3% IBA | $1.00^a\pm$ 0.44 | $1.83^a\pm$ 0.93 | $2.33^a\pm$ 1.20 |
| *P. fortunei* | Control | $1.00^a\pm$ 0.50 | $5.33^a\pm$ 2.67 | $2.83^a\pm$ 2.35 |
| | 0.1% IBA | $1.67^a\pm$ 0.33 | $4.83^a\pm$ 1.60 | $7.50^a\pm$ 1.04 |
| | 0.3% IBA | $1.00^a\pm$ 0.00 | $3.75^a\pm$ 0.52 | $1.56^a\pm$ 0.30 |

Means with the same letter superscript are not significantly different at 5% level.

**Table 5.** Difference in mean shoot number, shoot length and leaf number of stem cuttings between *P. elongata* and *P. fortunei* tree species.

| *Paulownia* Species | Mean Shoot Number | Mean Shoot Length (cm) | Mean Leaf Number |
|---|---|---|---|
| *P. elongata* | $1.25^a\pm0.19$ | $2.42^a\pm0.57$ | $3.84^a\pm0.72$ |
| *P. fortunei* | $1.22^a\pm0.20$ | $4.64^a\pm0.94$ | $4.00^a\pm1.17$ |

Means with the same letter superscript are not significantly different at 5% level.

**Fig. 4.** Over 48-day old plants of *Paulownia fortunei* developed from root cuttings by AAW.

**Fig. 5.** Rooted root cuttings of *Paulownia* fortunei tree species by AAW.

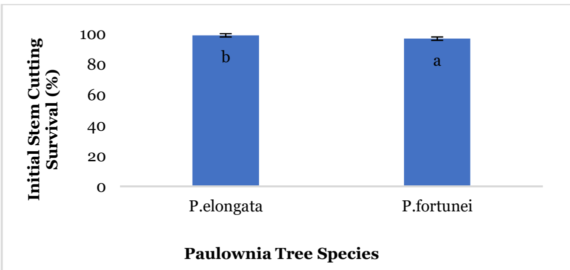


**Fig. 6.** The percentage of survival of stem cuttings between *P. elongata* and *P. fortunei* species.

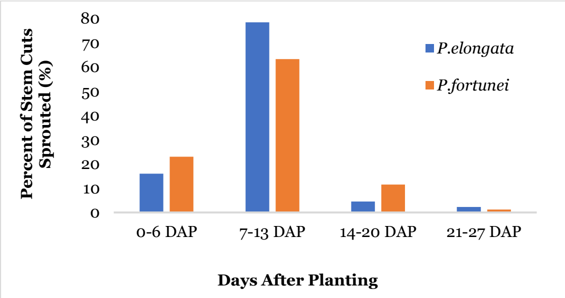


**Fig. 7.** The percentage of stem cuttings of *Paulownia* species sprouted days after planting.

**Fig. 8.** Evolving sprouts and leaves of stem cuttings of *Paulownia fortunei* by AAW.

## Discussion

When the *Paulownia* species were first introduced into Ghana, sexual propagation was used in the propagation exercise. Recent field assessment showed the inability of the trees to flower and produce viable seeds for further propagation. Therefore, the need to use simple, inexpensive but best vegetative propagation methods to multiply planting materials of *Paulownia* for field establishment. In this study, two vegetative propagation means (root and stem cuttings) were considered. Efficient vegetative propagation aimed at reproducing good quality propagules (clones) of plant species is an indispensable element for *Paulownia* clonal forestry. The use of vegetative propagation in multiplying planting materials of *Paulownia* for plantation is marked with many benefits than sexual propagation. *Paulownia* seeds are characterised with slow germination and seedling growth and development which is not the case of vegetative means of propagation (Bergmann and Moon, 1996). Vegetative propagation has been the primary means of producing plant materials of hybrids and varieties of *Paulownia*. Seeds are seldomly used in propagating *Paulownia* due to poor germination development (Drvodelić, 2018).

*Root Cutting Propagation of Paulownia Species*

The findings revealed the successes of root cutting propagation without the use of exogenous auxins, thus indicating the influence of the endogenous auxin contents of the *Paulownia* species. The root cuttings of the two *Paulownia* (*P. elongata* and *P. fortunei*) tree species survived irrespective of the levels of IBA. A significant variation ($P \leq 0.05$) was observed in the survival rate, sprouting and rooting abilities of the root cuttings between *P. elongata* and *P. fortunei* (Fig. 1). Cutting success is very important in the establishment of plant materials as the growth and rooting depend on the ability of the cuttings to survive (Antwi-Wiredu *et al.*, 2018).

It was observed that before the $28^{th}$ day of planting about 82.10% of *P. elongata* and 92.39% of *P. fortunei* of the root cuttings had sprouted. The control treatment appeared to perform well for the root cuttings of both *Paulownia* tree species. From all indications, the use of root cuttings in the regeneration of *Paulownia* planting materials for plantation is the best propagation option. Micropropagation by *in vitro* tissue culture and macropropagation involving the use of root cuttings are the two most effective means for the propagation and multiplication of *Paulownia* species. In many parts of the world, the commonest vegetative propagation technique for the multiplication of *Paulownia* species particularly, *elongata* has been root cutting. Any part of the root systems of *Paulownia* is capable of regenerating into a whole new tree (Salkic *et al.*, 2018).

All the treatments responded positively for the root cuttings of both *Paulownia* tree species. The percentage of cutting rooted, the number of roots per rooted cutting and the speed with which roots emerge and grow are the determinants of rooting capacity of cuttings (Leakey, 1985).

The influence of the application of auxin (IBA) did not vary statistically with the control treatment for the survival, sprouting and rooting potentials of the root cuttings of *P. elongata* and *P. fortunei* tree species. The success of cuttings in propagation lies with the ability to develop root to aid their acclimatization and subsequent field establishment (Fig. 5). In cutting propagation, adventitious rhizogenesis is a unique and complex process with its associated wounding, plant water relation, and the decline of correlative influences from the root system of parent stocks, regulated by many factors such as phytohormones, sugars, phenols state of parent stocks and genetic composition (Haissig, 1986).

*Stem Cutting Propagation of Paulownia Tree Species*

The use of semi and hardwood parts of tree stems (brown) usually lignified, perform poorly in vegetative propagation of tree species. After 30 days of planting, none of the stem cuttings rooted even though almost all of them developed shoots and leaves. Eventually, the stem cuttings lost all the developing sprouts/shoots and leaves because of the lack of root formation. Though in the first 14 days of planting about 95% showed signs of shoot and leaf formation, this development and growth did not persist after the $30^{th}$ day of planting. The death of sprouted cuttings could be attributed to lack of root formation to translocate nutrients and water, and rotting of the basal part of the cuttings (Antwi-Wiredu *et al*., 2018).

This current research about the inability of the stem cuttings to root even when they earlier sprouted goes to confirm that stem cuttings of *Paulownia* is unsuccessful. It is quite simple to propagate *Paulownia* tree species from seeds and root cuttings. The use of stem cuttings of *Paulownia* tree species for propagation is fruitless, thus inappropriate. It is relatively difficult to root stem cuttings of *Paulownia* tree species. Therefore, stem cuttings of *Paulownia* are rarely used in the propagation of the tree species (Zhu *et al.,* 1986).

Vegetative propagation capacity of trees is similar to that of herbaceous plants. Nevertheless, the decline in the rooting ability of trees at maturity due to complex structure and larger size needs to be avoided. It is necessary to overcome this challenge by the use of young plants, coppice or 'rejuvenated' shoots (Zimmermann, 1976). The capacity of trees to be propagated through vegetative means is significantly varied between species and genotypes influenced by physiological state and the environments (Leakey, 1985). Morphology, phenology and physiological age of parent stocks are among the many factors that cause rooting potentials of cuttings collected from lateral branches of mature trees (Stenvall *et al*., 2004, 2009, Snedden *et al*., 2010, Teklehaimanot *et al*., 2012). The carbohydrate, nutrient contents and growth regulators of parent plants affect the success of cuttings (Maile and Nieuwenhuis, 2010, Ky-Dembele *et al*., 2010, Dick and Leakey 2006).

**Conclusion**

The use of root cuttings of both *Paulownia* tree species (*P. elongata* and *P. fortunei*) for macropropagation exhibited higher survival rate. Even though the variation in survival rate was marginal, statistically, there was a significant difference ($P \leq 0.05$) between the *P. elongata* and *P. fortunei* root cuttings. Also, the majority of *P. elongata* and *P. fortunei* root cuttings started developing new shoots/sprouts before the $28^{th}$ day of planting. The sprouting and rooting growth success of the root cuttings of both *Paulownia* tree species performed and survived better irrespective of the influence of IBA treatments. There was no significant difference ($P \leq 0.05$) between the control and the IBA levels on the root cuttings success of *P. elongata* and *P. fortunei* tree species.

The propagation of stem cuttings of *P. elongata* and *P. fortunei* tree species was not successful, even though, they developed shoots and leaves, eventually, the cuttings died and rotted. It can be concluded that the root cuttings of both *Paulownia* (*P. elongata* and *P. fortunei*) tree species can be used in ensuring large scale production of planting materials for plantation establishment.

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