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CLONAL PROPAGATION OF *BROUSSONETIA PAPYRIFERA* BY STEM AND ROOT CUTTINGS

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ABSTRACT

Broussonetia papyrifera, locally known as 'York', is an introduced tree species in Ghana due to its potential for industrial cellulose, pulp, and paper production. Its unwanted spread in forest areas due to the introduction of both male and female plants has called for its control using approaches such as establishment of only male populations. This study assessed clonal propagation effects of cutting type and length on stem and root cuttings of male B. papyrifera plants. A factorial experiment comprising two factors: cutting type (leafy and non-leafy cuttings) and cutting length (5 cm, 10 cm and 15 cm) arranged in a Randomized Complete Block Design (RCBD) with four replications was set up for stem cuttings. For root cuttings, a single factor experiment comprising cutting lenghts (5 cm, 10 cm and 15 cm) in a RCBD was used. Non-leafy stem cuttings significantly ($p < 0.01$) produced longer (2.82 ± 0.34cm) and higher number of roots (1.67 ± 0.14) than leafy cuttings that had values of (2.00 ± 0.25 cm) and (1.16 ± 0.09) respectively 12 weeks after planting. Survival %, rooting %, number of leaves, dry root and shoot biomass were relatively higher for non-leafy but statistically similar to leafy cuttings. The 15 cm and 10 cm cuttings recorded significantly ($p < 0.001$) higher survival %, rooting %, number of leaves, number of roots, root length, dry root and shoot biomass than the 5cm cuttings. The interaction between cutting type and length significantly ($p \leq 0.01$) influenced only root length and dry root biomass. The length of root cuttings had a significant ($p \leq 0.01$) influence on the propagation ability of B. papyrifera 10 weeks after planting. The results indicate that B. papyrifera is amenable to clonal propagation but further studies are required to improve the rooting of cuttings using different leaf areas and growing media, rooting hormones, and different cuttings types or sizes.

Keywords: *Broussonetia papyrifera*, clonal propagation, stem cuttings, root cuttings

INTRODUCTION

Broussonetia papyrifera is a fast-growing pioneer (Tanasombat *et al*., 2005), medium-sized, exotic, deciduous woody species (Agyeman *et al*., 2016) and non-leguminous tree (Saito *et al*., 2009). It can attain an average height of 10 to 21 m and 70 cm in diameter at breast height (dbh) (Apetorgbor & Bosu, 2011). The species is native to temperate climates but is now adapted to diverse latitudes and grows in many types of habitats (Seelenfreund *et al*., 2011). The species naturally grows in various environments in Asia and Pacific countries (Kuang *et al*., 2012). It is native to eastern Asia (Li *et al*., 2011), southwest China (Liao *et al*., 2014), Taiwan (Whistler & Elevitch, 2006), common in Japan and widespread in tropical and subtropical regions (Malik & Husain, 2007). It also occurs in South America – Argentina and North America – Florida, Texas, Vermont, Kansas, New York City, etc. (Morgan & Overholt, 2016). In Europe, the species has been naturalized in the Southern parts (Chung *et al*., 2017; González-Lorca *et al*., 2015). In Africa, the species is found in Uganda and Ghana (Apetorgbor & Bosu, 2011). In Ghana, the species was introduced by the Forestry Research Institute of Ghana (FORIG) in 1969 as part of an experimental programme (Kyereh *et al*., 2014) to evaluate its potential for industrial cellulose, pulp, and paper production (Adigbli *et al*., 2018). Its estimated distribution covers nearly 81,000 km^2 of closed forest zones in Ghana (Bosu *et al*., 2013). Viable populations of the species are reportedly found as far north as Dormaa-Ahenkro near the Ghana-Cote d'Ivoire border (Kyereh *et al*., 2014).

Like many other plant species, B. *papyrifera* has been used for a variety of purposes around the world (States *et al*., 2016). The leaves serve as fodder for many livestock animals, e.g. West African Dwarf sheep, in Ghana (Afriyie, 2016) and have been employed in wastewater remediation when turned into powder (Nagpal *et al*., 2010). Also, it has been used in the rehabilitation of coal mines in Indonesia (Hamanaka *et al*., 2014), phytoremediation of Lead (Pb) in China (Kang *et al*., 2018), and as a fallow crop in upland rice rotation systems in Northern Laos (Saito *et al*., 2009). The bark is highly fibrous and used in paper and textile industries in Southeast Asia. It has also been used as an intercrop in mixed Agriculture systems in Tonga (Whistler & Elevitch, 2006). Naturally, the species spreads both by seed and through vegetative propagation (Swearing, 2005). The species can reproduce itself through sprouting from root suckers, stumps and seedlings from the soil seed bank (Kyereh *et al*., 2014). Artificially, unconventional means of stem cuttings and root cutting have been used in propagating the species in Taiwan (Whistler & Elevitch, 2006). It grows faster and can spread with little human mediation.

There is a concern with introducing the plant into new places, because of its invasiveness. Its invasive rate is significantly high in Ghana due to the introduction of both male and female plants (Addo-Fordjour *et al*., 2009). The presence of male and female plants in close proximity permits pollination of female flowers, seed development and seed dispersal. Individual female trees can produce hundreds of fruits and thousands of seeds, and readily colonize or invade open habitats. Conversely, B. *papyrifera* is not invasive in countries where only male clones were introduced (Peñailillo *et al*., 2016). This implies that one way of avoiding the unwanted spread of the species whilst taking advantage of its desirable characteristics is to find means of establishing male populations only in areas where it will be needed to fulfil an ecological or economic need. A way to achieve this is to isolate and propagate male clones for multiplication.

Amongst the various techniques of vegetative propagation, the employment of stem cuttings is pivoted as the most efficient and low-cost method. Nevertheless, the success of this method depends on numerous factors such as leaf area, stem length, age of the stock plant used and position on the stem from which cuttings are taken. Also, treatment of the cuttings including control of environmental conditions and application of plant growth regulators has proved useful in determining the rooting success of many species (Ky-dembele *et al*., 2011). However, while different plant species respond differently to various propagation treatments such as cutting size, hormone application, different growing media etc., the growth responses of B. *papyrifera* to varied cutting types and lengths have rarely been studied. Therefore, this study determined the effects of cutting type and cutting length on the rooting of stem and root cuttings of male B. *papyrifera* plants.

METHODOLOGY

Study site

The study was conducted at the campus of Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana, with a geographic coordinate of 6.6745° N, 1.5716° W (Fig. 1). The area is within a moist semi-deciduous forest agro-ecological zone with a bimodal pattern of rainfall (i.e., high in April-June and low in September-October). A short dry period is experienced in August, and a long dry period (i.e. harmattan) from December to March. The mean annual rainfall is approximately 1,350 mm, with a humidity of 68%, and a mean temperature of 26.6ºC (Antwi-Boasiako & Enninful, 2011).

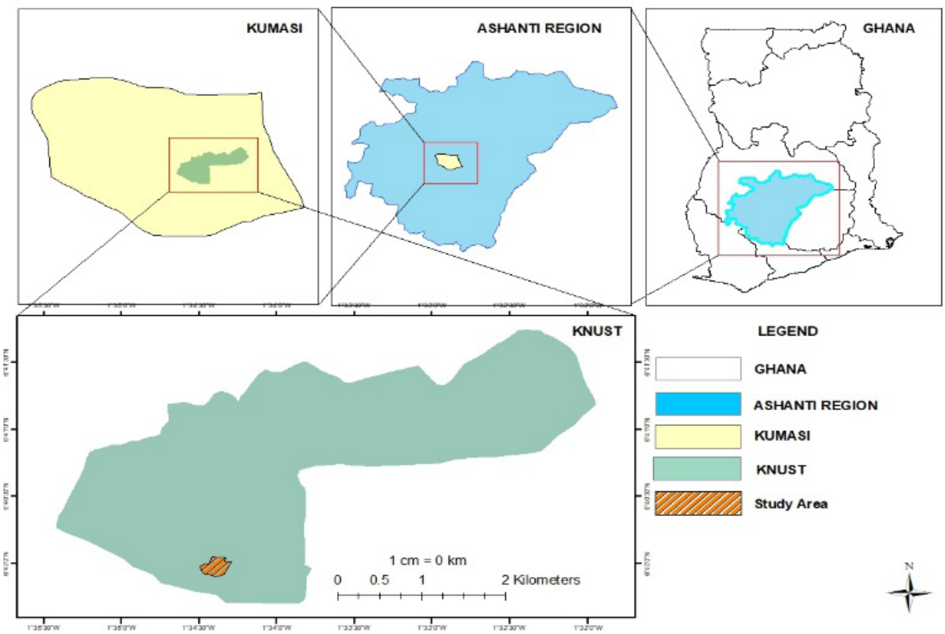

Figure. 1: Map of study area

Sources and Preparation of Cuttings

Semi-hardwood stem cuttings were collected from 60 male *B. papyrifera* plants (with dbh ranging from 9 – 41 cm) in the KNUST Botanical garden. The cuttings were grown in perforated black polypot bags filled with coco peat in a non-mist propagating system at the nursery. Stem cuttings (Plate 1a & 1b) were harvested early in the mornings and placed in Ziploc bags to prevent drying before being taken to the nursery. Leaves were trimmed in cuttings to prevent desiccation. To minimize fungal attacks, cuttings were soaked in a Nordox 75 (75% cuprous oxide) fungicide solution for 5 minutes before planting. The cuttings were then planted at a depth of 30% of its length in a rooting medium consisting of solar-sterilized coco peat in black polypot bags. The cuttings were regularly watered manually to avoid desiccation. The experiments ran for 12 weeks. Secondly, root cuttings (Plate 1c) were harvested from the same plants used for stem cuttings. Cuttings were placed in Ziploc bags to prevent drying and sent to the nursery. Cuttings were treated and inserted horizontally in coco peat serving as a growing medium.

(a)

(b)

(c)

Plate 1. Leafy stem cutting (a), Non-leafy stem cutting (b) and Root cutting (c) of *B. papyrifera*

Experimental design

Effects of cutting type and cutting length of stem cuttings

To test the effect of cutting type and cutting length on rooting ability, a factorial experiment arranged in a Randomized Complete Block Design (RCBD) with four replications was set up. The first factor was cutting type with two levels: leafy and non-leafy cuttings. The second is cutting length with three levels (5 cm, 10 cm and 15 cm). Each replication consisted of 120 cuttings. In total, 2,880 cuttings were used for the stem-cutting experiment. Leaves on leafy cuttings were removed leaving one leaf trimmed to half. Cuttings had an average diameter of 0.4 – 0.6 cm.

Effects of cutting length of root cuttings

To examine the effects of cutting length on root cuttings, a single-factor experiment comprising cutting length at three levels (5 cm, 10 cm and 15 cm) and arranged in an RCBD with 4 replications and 20 cuttings per replication was used. In total, 240 cuttings were used for the root-cutting experiment. Cuttings had an average diameter of 1.5 – 2 cm.

Data collection

Twelve (12) weeks after planting, data on the growth performance of stem cuttings (survival percentage, rooting percentage, number of leaves, number of roots, root length (Plate 2a), dry root (Plate 2b) and dry shoot (Plate 2c) biomass were recorded.

For root cuttings, data on survival percentage, number of sprouts, height of sprouts (Plate 3a), diameter of sprouts (Plate 3b) and number of leaves were recorded 10 weeks after planting.

DATA ANALYSIS

Data recorded for the various parameters of propagated stem and root cuttings were subjected to an analysis of variance (ANOVA) test. Tukey's pairwise comparison was used to determine the differences between means of both stem and root cuttings when significant effects were detected. All data analyses were done using PAST Software v4.03. The results were presented in tables.

(a)

(b)

(c)

Plate 2. Measurement of root length using meter rule (a), dry shoot biomass (b) and dry root biomass (c) with electronic balance for propagated stem cuttings

(a) (b)

Plate 3. Measuring the height of the sprout with meter rule (a) and diameter of the sprout with a caliper (b) for root cuttings

RESULTS AND DISCUSSION

Effects of cutting type and cutting length on growth of propagated stem cuttings

Results indicated that cutting type, cutting length and their interaction had a significant ($p \leq 0.05$) influence on the propagation ability of *B. papyrifera*. Cutting type significantly affected the number of roots ($F_{(1,15.46)}$, p = 0.00) and length of root ($F_{(1,9.77)}$, p = 0.00) but not survival percentage, rooting percentage, number of leaves, dry root biomass and dry shoot biomass (Table 1). Non-leafy cuttings significantly ($p < 0.01$) produced longer (2.82 ± 0.34 cm) and higher number of roots (1.67 ± 0.14) compared with (2.00 ± 0.25 cm) and (1.16 ± 0.09) respectively obtained for leafy cuttings. Retention of leaves on stem cuttingshas an important role in rooting induction, because leaves are the production center of hormones and photo-assimilates in great quantities (Zem *et al.,* 2016; Deloso *et al.,* 2020). Also, Tchoundjeu & Leakey (2001), Solis *et al.* (2016) and Belniaki *et al.* (2018) due to the genus denomination in the past. This ornamental plant species has been gaining importance in the floristic industry due to the great number of exotic cultivars available in the market. Coleus commercial exploitation by seeds is held up by genetic instability, which makes it usually being propagated through semi-hardwood stem cuttings and leaves have great importance in stem cuttings adventitious rooting. The objective of this study was to evaluate the presence or absence of apical leaves and the use of indolebutyric acid (IBA established the importance of leaves for the survival and good performance of stem cuttings.

However, our findings suggest that the retention of leaves on stem cuttings may not enhance the propagation success and growth of *B. papyrifera*. This is because, aside from having significantly longer and higher numbers of roots for non-leafy cuttings, values for survival percentage, rooting percentage, number of leaves, dry root biomass and dry shoot biomass were statistically similar to that of leafy cuttings. As explained in other studies, this could be attributed to size and number of the leaves retained (Ofori *et al.,* 1996; Benbya *et al.,* 2021), shorter duration of the retained leaves before abscission (Thomas & Schiefelbein,

2004) which occurred 3 days after planting per our study, the photosynthetic inactiveness of the retained leaves (Takoutsing *et al.,* 2017) or water loss in stem cuttings with retained leaves (Deloso *et al.,* 2020). Our findings contradict the findings on *Argania spinosa* where successful vegetative propagation was restricted to leafy stem cuttings with 2 – 8 leaves retained during the study (Benbya *et al.,* 2021). Similarly, a study on *Khaya senegalensis* cuttings revealed that leafy cuttings rooted well (80%) compared to leafless cuttings (0%) (Ky-Dembele *et al.,* 2011).

Table 1. Effects of cutting type on the survival percentage, rooting percentage, number of leaves, number of roots, root length, dry root and shoot biomass of propagated *Broussonetia papyrifera* stem cuttings

Parameter	Leafy	Non-leafy	*p*-value
Survival %	71.70 ± 3.38[a]	74.80 ± 3.86[a]	0.25[ns]
Rooting %	60.27 ± 2.92[a]	62.34 ± 2.30[a]	0.47[ns]
No. of leaves	1.89 ± 0.15[a]	2.11 ± 0.17[a]	0.18[ns]
No. of roots	1.16 ± 0.09[b]	1.67 ± 0.14[a]	0.00***
Root length (cm)	2.00 ± 0.25[b]	2.82 ± 0.34[a]	0.00***
Dry root biomass (g)	0.09 ± 0.01[a]	0.09 ± 0.01[a]	0.96[ns]
Dry shoot Biomass (g)	0.15 ± 0.02[a]	0.15 ± 0.03[a]	0.93[ns]

***** Significant at ($p < 0.001$). [ns] Not significant at ($p > 0.05$). Means ± SE (standard error) followed by the same letter(s) are not significantly different at the 5% level according to Tukey's multiple comparison test.**

Cutting length had a significant ($p < 0.001$) effect on all the parameters evaluated (Table 2). Stem cuttings have been widely used in the propagation of several tropical tree species such as *Cordia africana* (Ambebe *et al*., 2018), *Terminalia chebula* (Babu *et al.*, 2018) and *B. papyrifera* (Kyereh *et al*., 2014). Rooting is one important process in plant development. The initial cutting length (and size) of stem cuttings during propagation is one important factor (Leakey, 2014) for cuttings to root and eventually survive. Generally, the 15cm and 10cm cuttings recorded significantly ($p < 0.001$) higher values for survival %, rooting %, number of leaves, number of roots, root length, dry root and shoot biomass than the 5cm cuttings (Table 2). However, aside from rooting % and root length where the 15cm recorded significantly higher values than 10cm cuttings, values for survival %, number of leaves, number of roots, dry root and shoot biomass were similar for both lengths of cutting (Table 2). The present study demonstrates that increasing the cutting length of *B. papyrifera* stem cuttings resulted in better survival and growth of cuttings. The most probable reason for better survival and growth of longer cuttings (15 cm) of *B. papyrifera* might be due to more food (carbohydrates) reserves holding other factors constant.

Table 2. Effects of cutting length on the survival percentage, rooting percentage, number of leaves, number of roots, root length, dry root and shoot biomass of propagated Broussonetia papyrifera stem cuttings after 12 weeks

Parameter	5cm	10cm	15cm	*p*-value
Survival %	60.3 ± 2.6^b	74.00 ± 2.3^a	85.50 ± 2.34^a	1.62E-^{06} ***
Rooting %	50.59 ± 2.75^c	64.45 ± 1.74^b	68.88 ± 2.27^a	0.000129 ***
No. of leaves	0.84 ± 0.12^b	2.12 ± 0.17^a	3.06 ± 0.13^a	9.12E-^{19} ***
No. of roots	0.64 ± 0.10^b	1.55 ± 0.13^a	2.05 ± 0.13^a	8.22683E-^{14} ***
Root length (cm)	0.37 ± 0.08^c	2.17 ± 0.22^b	4.68 ± 0.35^a	2.15217E-^{24} ***
Dry root biomass (g)	0.02 ± 0.00^b	0.08 ± 0.01^a	0.17 ± 0.01^a	1.58E-^{25} ***
Dry shoot biomass (g)	0.02 ± 0.00^b	0.11 ± 0.02^a	0.33 ± 0.04^a	3.36074E-^{16} ***

***** Significant at p < 0.001, Means ± SE (standard error) followed by the same letter(s) are not significantly different at the 5% level according to Tukey's multiple comparison test**

The relationship between rooting and cutting length has been reported for a number of tropical species, such as *Eucalpytus spp.* (Naidu and Jones, 2009), *Duranta repens* (Ibironke, 2013), and *Tinospora crispa* (Aminah *et al*., 2015). Our study findings also show that rooting percentage, number of roots, root length, dry root and shoot biomass were significantly ($p \leq 0.01$) influenced by the length of *B. papyrifera* cuttings with higher values recorded for longer cuttings than shorter ones. Conversely, there have been reports where cuttings with shorter lengths rooted better or performed better than their longer counterparts. For instance, Ofori *et al*. (1997) recorded a decline in percentage rooting, the mean number of roots with increasing cutting lengths amongst 3cm, 9cm, 12cm and 15cm cutting lengths of *Milicia excelsa* stem cuttings. They also observed an increase in mortality with increasing cutting length. This observation could be explained by factors such as the physiological age of plant stock (Owusu, 2011), microbial infection (Leakey, 2014), or unfavorable propagating environment.

Although there may be a negative relationship between the length of cutting and the ability to root, our results confirm the assumption that the level of carbohydrates in cuttings influences the survival and rooting of stem cuttings after severance from the parent plant. Such relationships between cutting length and rooting ability are perceived to reflect the importance of carbohydrate reserves stored in the stem, which support adventitious root development (Ky-dembele *et al*., 2011).

Significant interactive effects between cutting type and cutting length were observed on root length ($F_{(2,5.4)}$, $p = 0.01$) and dry root biomass ($F_{(2,5.79)}$, $p = 0.00$) but not survival and rooting percentage, number of leaves, number of roots, and dry shoot biomass (Table 3). Cuttings of length 15 cm without leaves recorded the highest survival and growth performance compared to cuttings with other combinations of these two factors. In general, cuttings of shorter lengths (5 cm and 10 cm) had fewer carbohydrate reserves essential for the rooting process, which, could not be improved with leaf retention suggesting that retention of leaves may be disadvantageous to the species in its ability to sprout.

Table 3. The interactive effects of cutting length and type on the survival percentage, rooting percentage, number of leaves, number of roots, root length, dry root and shoot biomass of propagated Broussonetia papyrifera stem cuttings after 12 weeks

Parameters	5cm. L (T4)	5cm.nL(T1)	10cm.L(T5)	10cm.nL(T2)	15cm.L(T6)	15cm.nL(T3)	*p*-value
Dry shoot biomass (g)	0.01 ± 0.00^{a}	0.02 ± 0.00^{a}	0.14 ± 0.02^{a}	0.07 ± 0.01^{a}	0.30 ± 0.04^{a}	0.36 ± 0.06^{a}	0.15^{ns}
Dry root biomass (g)	0.02 ± 0.01^{b}	0.01 ± 0.00^{bd}	0.10 ± 0.02^{bc}	0.06 ± 0.01^{b}	0.16 ± 0.01^{ac}	0.19 ± 0.01^{a}	0.01**
Root length (cm)	0.34 ± 0.14^{b}	0.40 ± 0.08^{b}	2.00 ± 0.28^{bc}	2.36 ± 0.35^{bc}	3.67 ± 0.45^{ac}	5.70 ± 0.43^{a}	0.01**
Number of roots	0.51 ± 0.11^{a}	0.78 ± 0.15^{a}	1.32 ± 0.14^{a}	1.79 ± 0.22^{a}	1.65 ± 0.06^{a}	2.45 ± 0.21^{a}	0.26^{ns}
Number of leaves	0.76 ± 0.17^{a}	0.91 ± 0.18^{a}	2.04 ± 0.22^{a}	2.20 ± 0.27^{a}	2.88 ± 0.16^{a}	3.24 ± 0.21^{a}	0.85^{ns}
Rooting percentage	49.18 ± 4.46^{a}	52.00 ± 3.76^{a}	63.90 ± 2.38^{a}	65.05 ± 2.87^{a}	67.73 ± 2.08^{a}	70.03 ± 4.35^{a}	0.97^{ns}
Survival percentage	62.00 ± 4.92^{a}	58.50 ± 2.34^{a}	69.25 ± 2.29^{a}	78.75 ± 2.10^{a}	83.75 ± 3.84^{a}	87.25 ± 2.95^{a}	0.16^{ns}

**** Significant at $p \leq 0.01$, ^{ns} Not significant at $p > 0.05$. Means ± SE (standard error) followed by the same letter(s) are not significantly different at the 5% level according to Tukey's multiple comparison test**

Our study findings suggest that cutting length might be more important than cutting type during the propagation of *B. papyrifera* and that, the production of photosyntate by leaves may not be required to enable rooting of stem cuttings after severance from the parent plant. The poor retention of leaves suggests the potential for leafy cuttings may be low for the species as its employment may cause necrosis of cuttings through stress.

Effects of cutting length on the growth of propagated root cuttings

Results indicated that the length of root cuttings had a significant ($p \leq 0.01$) influence on the propagation ability of *B. papyrifera* (Table 4). Cutting length significantly affected survival percentage ($F_{(2,24.16)}$, p = 0.00), diameter of sprouts ($F_{(2,4.84)}$, p = 0.03) and number of leaves ($F_{(2,6.37)}$, p = 0.01) but not the height and number of sprouts produced (Table 4). Longer root cuttings (10cm and 15cm) resulted in higher survival (76.25 - 81.25%), diameter of sprouts (0.16 - 0.18cm) and number of leaves (4 - 5). In a related study, the length of root cuttings significantly affected sprouting efficiency ($p < 0.00$) with 10 and 20cm cutting lengths recording higher sprouting percentages, number of sprouts, diameter and length of sprouts compared to the 5cm root cuttings of *Detarium microcarpum* (Ky-Dembele *et al*., 2010). While our findings showed the regenerative abilities of *B. papyrifera* through root cuttings, Kouakou *et al*. (2016) reported that no regeneration was observed for propagated root cuttings of *Garcinia kola* regardless of the size, nursery type and hormonal treatment. Also, studies on root cuttings of *Morus alba* showed maximum root length, root number, root diameter, root dry and fresh weight in 5 cm followed by 10 cm, 15 cm and 20 (Ahmad *et al*., 2011).

The varied results obtained for different species in connection with root cuttings relate to a statement by Kouakou *et al*. (2016) who indicated that experience with regeneration from root cuttings is much more limited, and appears to be species-specific. In the present study root cuttings of length 15 cm had better growth compared to 10 cm and 5 cm. Our findings conform to a study by Zou *et al.* (2022) who indicated that longer root cuttings of *B. papyrifera* regenerate better than shorter ones. We observed that at a uniform diameter, longer root cuttings potentially possessed a higher ability to store resources needed for regeneration. Hence, the significant effect of cutting length on the observed growth performance could be attributed to high storage reserves (Gudagi *et al.,* 2020).

Table 4. Effects of cutting length on survival %, number of sprouts, number of leaves, diameter of sprouts and height of sprouts for propagated *B. papyrifera* root cuttings after 10 weeks

Parameter	5cm	10cm	15cm	*p*-value
Survival %	62.5 ± 2.02^{b}	76.25 ± 2.29^{a}	81.25 ± 1.55^{a}	0.00 ***
No. of sprouts	1.30 ± 0.05^{a}	1.37 ± 0.04^{a}	1.42 ± 0.04^{a}	0.21^{ns}
Height of sprouts (cm)	2.76 ± 0.32^{a}	7.86 ± 2.08^{a}	10.84 ± 3.30^{a}	0.07^{ns}
Diameter of sprouts (cm)	0.12 ± 0.01^{b}	0.16 ± 0.01^{ab}	0.18 ± 0.02^{a}	0.03 *
No. of leaves	2.27 ± 0.33^{b}	4.10 ± 0.40^{ab}	5.36 ± 0.93^{a}	0.01**

*****, **, * Significant at $p \leq 0.001$, $p \leq 0.01$ and $p \leq 0.05$ respectively; ^{ns} Not significant at $p > 0.05$. Means ± SE (standard error) followed by the same letter(s) are not significantly different at the 5% level according to Tukey's multiple comparison test.**

CONCLUSION

This study has shown that *B. papyrifera* is amenable to vegetative propagation by stem or root cuttings. Stem cuttings (without leaf) with a length between 10 and 15 cm are appropriate to enhance the survival and subsequent rooting of the cuttings to develop into independent plantlets. Employing coco peat as a growing medium is important in the rooting process. Root cuttings of length 10 – 15 cm in coco peat growing medium significantly had higher survival, diameter and number of leaves for the sprouts. This study underscores the potential to propagate male clones of *B. papyrifera* stems and roots for introduction into landscapes in order to harness its multiple benefits. To perfect the propagation protocol for stem and root cuttings, further studies are required to improve the rooting of cuttings using different leaf areas and growing media, rooting hormones, and different cuttings types or sizes.

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DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest.

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