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Vegetative propagation of African Blackwood (*Dalbergia melanoxylon* Guill. & Perr.): effects of age of donor plant, IBA treatment and cutting position on rooting ability of stem cuttings

E. Amri · H. V. M. Lyaruu · A. S. Nyomora · Z. L. Kanyeka

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Abstract A study to determine the best vegetative propagation protocol was carried out for *Dalbergia melanoxylon.* Natural regeneration of *D. melanoxylon* is limited due to poor seed viability and germination. The effects of age of donor plant, indole-3-butyric acid (IBA) treatment and cutting position on rooting of stem cuttings were investigated. The effect of age of donor plant was significant ($P < 0.001$) only for percent rooting, position effect was significant for all studied parameters, and IBA treatment at 300 ppm was insignificant only for percent callusing. Interactive effects of cutting position × age of donor and cutting position × IBA treatment were significant for percent rooting and root number per cuttings while interactive effect of age × IBA was significant only for percent rooting. Observed difference in rooting performance could be due to uneven distribution of root promoting and inhibiting substances with respect to age of donor plant and IBA which intensified root formation. Cuttings from juvenile donor plant performed better in all rooting parameters than mature donor plant. The highest percentages in rooting were (71.11%) and (24.42%) for cuttings from juvenile and mature donor plants, respectively. IBA treated cuttings produced higher percentage rooting, number of roots and root length than untreated cuttings which revealed a strong IBA influence on rooting ability of stem cuttings in *D. melanoxylon.* It was concluded that stem cuttings should be taken from juvenile donor plants and basal cutting position should be used to produce high quality planting stock material for the afforestation and conservation programme of *D. melanoxylon.*

Keywords *Dalbergia melanoxylon* · Domestication · IBA · Vegetative propagation · Cutting position · Non-mist propagator

E. Amri · H. V. M. Lyaruu · A. S. Nyomora · Z. L. Kanyeka
Department of Botany, University of Dar es Salaam, P. O. Box 35060, Dar es Salaam, Tanzania

E. Amri (✉)
Dar es Salaam Institute of Technology, P. O. Box 2958, Dar es Salaam, Tanzania
e-mail: ezekielamri@yahoo.com

Introduction

African Blackwood (*Dalbergia melanoxylon* Gill. & Perr.) is an economically important tree with high-quality wood and one of the most expensive timbers in the world (Jenkins et al. 2002). *D. melanoxylon* is used for the manufacturing of musical instruments and decorative objects such as carvings (Burkill 1995). As a result of the valuable products derived from *D. melanoxylon*, high exploitation pressure has been exerted to the extent of threatening future existence in its natural habitats (Hamisy and Hantula 2002; Jenkins et al. 2002). *D. melanoxylon* is considered by the International Union for conservation of Nature (IUCN) Red List as Lower Risk/near threatened (LR/nt) species (World Conservation Monitoring Centre 1998).

To curb further deterioration of the remaining natural populations, sustain the supply of the raw material and increase the overall productivity, domestication of *D. melanoxylon* is considered important (Mbuya et al. 1994). However, so far little success has been achieved in domesticating the species due to several silvicultural problems associated with its propagation among others. Natural regeneration of *D. melanoxylon* is limited as the species is usually raised from the seeds with poor germinations (Nshubemuki 1993). Moreover, seeds of *D. melanoxylon* do not retain their viability for more than 1 year (Mbuya et al. 1994). A trial to improve seed germination through various pre-sowing treatments has shown little success (Msanga 1998). These problems coupled with increased demand of *D. melanoxylon* for international trade calls a need to use of vegetative propagation as an important alternative to the use of seed.

Vegetative propagation is considered ideal in rapid multiplication of a species under threat while trying to maintain certain desired characteristics (Hartmann et al. 2002; Tchoundjeu et al. 2004). However, rooting ability of tree species through stem cuttings is markedly affected by several factors such as cutting position from the shoot, age of the donor plant and IBA treatment (Hartmann et al. 2002; Husen and Pal 2006). Variations in rooting ability for cuttings taken from different positions from the shoot are often observed (Al-Salem and Karam 2001; Agbo and Obi 2007). Different cutting positions from the shoot influence the overall quality, rooting ability and subsequent growth habit of rooted stem cuttings (Tchoundjeu and Leakey 1996; Husen and Pal 2003). Effect of age of donor plant on rooting ability of stem cuttings has been reported in many trees (Stenvall et al. 2004; Bhardwaj and Mishra 2005; Husen and Pal 2007a). Variation in rooting ability of stem cuttings taken from different ages of donor plants has been described that could be due to decrease in the content on endogenous auxins or decreased sensitivity of aging tissues to rooting promoters and/or accumulation of inhibitory substances which inhibit rooting (Husen and Pal 2006). It is well established fact that growth regulators such as IBA play an important role in controlling the rooting ability of stem cuttings (Tchoundjeu et al. 2002; Gateablé and Pastor 2006; Husen and Pal 2007a).

Currently, there is no feasible optimised method for vegetative propagation of *D. melanoxylon* through stem cuttings. Given the economic importance of the species, this study investigated the domestication potential of *D. melanoxylon* through determining the effect of cutting position, age of donor plant, IBA treatment and their interactive effects on rooting of *D. melanoxylon* stem cuttings.

Materials and methods

Plant material source and cuttings preparation

Source of cuttings materials were taken from two types of explants namely juvenile donor plants and mature donor plants. Juvenile donor plant cuttings were taken from 3 years old seedlings all from one open-pollinated family grown in nursery while mature donor plant cuttings were taken from 15 years old mature plants. Both juvenile and mature donor plant cuttings were collected from Mkundi provenance in Morogoro, Tanzania. From each age a total of 60 donor plants were used. Proper physiological condition that promotes ready adventitious rooting and freedom from insects and disease were considered for selection of both juvenile and mature donor plants. Seedlings and cuttings of mature donor plant enclosed in a polythene bags were transported to the propagation site at the Department of Botany, University of Dar es Salaam.

Cuttings for both juvenile and mature donor plants were divided into three cutting positions from their shoots namely apical, middle and basal position of stem cuttings. Cutting positions were assigned starting at node 4 from the apex of the shoots as apical, followed by middle and basal positions sequentially down the shoots for both juvenile and mature cuttings. Seedlings height ranged from 54 to 71 cm; the cuttings positions from these juvenile donor plants were cut having length of 15 cm and a diameter of 0.4–1.0 cm. Cuttings from shoots mature donor plant were cut having a length of 20 cm and diameter range of 0.8–1.4 cm. Lengths of cuttings were kept 15 cm for juvenile compared to 20 cm for mature due to short seedlings shoot heights which could not be possible to get three cutting positions per shoot.

Experimental design

Spilt-split plot experimental design was used whereby the experiment had three factors: age donor plant, IBA treatment and cutting position. Major treatment factor was the age of donor plant which had two levels (juvenile and mature), sub major treatment factor was IBA treatment which also had two levels (300 and 0 ppm) and minor treatment factor was the cutting position which had three levels (apical, middle and basal position). Based on earlier findings by Amri 2002 on trial for determination of optimal IBA concentration, 300 ppm IBA was selected for this experimentation as it has given higher rooting in cuttings *D. melanoxylon.* Each treatment factor was replicated three times.

Ten cuttings were used per replicate such that with the three replications a total of 360 cuttings were used for the whole experiment (i.e. 10 cuttings $\times$ 3 replications $\times$ 2 age of donor plant $\times$ 2 auxin treatments $\times$ 3 cutting positions). Treated basal ends of each stem cutting of *D. melanoxylon* were air dried briefly for 5 min before insertion to a depth of 15–25 mm in sand used as rooting media in a non-mist propagator.

Non-mist propagator

Non-mist propagator was constructed following a design as described by Leakey et al. (1990). It was a wooden frame (length: 1.8 m; width: 1 m; height: 60 cm at one end and 45 cm at the other end) enclosed in a single sheet of polythene such that the base was completely water tight and the lid was airtight. The frame was covered tightly with a single piece polythene and closely fitting lid. The polythene base of the propagator was covered

in a thin layer of sand to protect the polythene and onto this was placed large stones to a depth of 10–15 cm. This was then covered by successive layers of small stones and gravel to a total depth of 20 cm. The spaces between stones and gravel were filled with water. The saturated layers of stones and gravel were covered by the sand as rooting media. The propagator was kept under bamboo made shed to avoid excessive heat accumulation. Humidity in the propagators was maintained at 85 ± 2% and maximum and minimum day–night temperature at 30 ± 1 to 25 ± 1°C, respectively. Whenever the propagator was opened for observation, fine jet of water spraying was applied to raise the relative humidity inside the propagator.

Data recording and evaluation

Data were collected in terms rooting parameters as rooting percentage, root number, root length and callus formation for per cutting. Evaluation of cuttings was made after 50 days from day of planting and a cutting was considered rooted if it has at least one primary root ≥1 mm long. For root measurements, the sand was removed from the rooted cuttings their roots washed and separated from the cuttings before subjecting to the root number and root length.

Data analysis

Data analysis was done using Genstat 5 Release 7.2 DE computer software package. The analysis of variance (ANOVA) procedures were used to test for significant effect of treatments, followed by Duncan's Multiple Range Test (DMRT) for comparisons of different means of different treatments. Before analysis, rooting and callus percentages were converted by arc-sine transformation, whereas, root number was converted by square root transformation to meet the normality assumption for the analysis of variance (Gomez and Gomez 1984).

Results

Main effects

The effect of age of donor plant was highly significant ($P < 0.001$) only for percent rooting among rooting parameters evaluated (Table 1). DMRT revealed that juvenile cuttings had significant higher rooting percentage, root number and root length than mature cuttings except for percent callusing which was higher in mature cuttings (Table 2). The effect of IBA treatment was highly significant ($P < 0.001$) for rooting percentage, root number and root length and was insignificant for percent callusing (Table 1). DMRT revealed that IBA treated cuttings at 300 ppm had significantly higher rooting percentage, root number, root length than cuttings treated at 0 ppm (Table 2). The effect of cutting position was highly significant ($P < 0.001$) for percent rooting, root number, root length and percent callusing (Table 1). Mean separation by DMRT showed that cuttings taken from the basal position had significantly highest percent rooting, root number, root length and percent callusing per cutting followed by middle and upper part (Table 2). Highest percent rooting for basal cutting position was 35.8 ± 3.7%, while the highest root number was 7.25 ± 1.34 (Table 2).

Table 1 Analysis of variance for the effect of age of donor plant, IBA treatment, cutting position and their interactions on rooting parameters of *D. melanoxylon*

Source of variation	*df*	Mean squares			
		Rooted cuttings (%)	Root number	Root length (cm)	Callused cuttings (%)
Replicate blocks	2	2.78^{ns}	0.10^{ns}	1.21^{ns}	144.44^{ns}
Age of donor plant	1	6,136.11*	126.56^{ns}	14.44^{ns}	$1{,}600.0^{ns}$
Error (a)	2	2.78	0.13	0.83	33.33
IBA treatment	1	18,225.0*	532.84*	218.05*	900.0 NS
Age of donor plant × IBA treatment	1	3,802.78*	60.06^{ns}	1.52^{ns}	544.44^{ns}
Error (b)	4	13.89	4.15	0.34	22.22
Cutting position	2	1,302.78*	88.94*	16.42*	419.44*
Cutting position × age of donor plant	2	352.78*	38.01*	4.19^{ns}	325.00*
Cutting position × IBA treatment	2	608.33*	52.63*	6.62*	208.33^{ns}
Cutting position × IBA treatment × age of donor plant	2	36.11^{ns}	15.89 NS	0.32^{ns}	136.11^{ns}
Pooled error (c)	16	29.17	3.02	0.46	22.22

ns not significant

* Significant at $P < 0.001$

Table 2 Effect of age of donor plant, IBA treatment and cutting position on rooting percentage, number of roots, root length and callusing percentage for *D. melanoxylon* stem cuttings

Variables		Rooted cuttings (%)	No. of roots/ cutting	Root length (cm)	Callused cuttings (%)
Age of donor plant	Juvenile	40.58 ± 5.73^{a}	6.31 ± 1.77^{a}	3.51 ± 0.77^{a}	1.11 ± 0.76^{a}
	Mature	14.9 ± 3.2^{b}	2.55 ± 0.68^{b}	2.55 ± 0.57^{b}	14.44 ± 3.72^{b}
IBA treatment (ppm)	0	2.94 ± 0.82^{a}	0.61 ± 0.13^{a}	0.45 ± 0.14^{a}	2.94 ± 0.82^{a}
	300	47.64 ± 4.26^{b}	8.57 ± 1.36^{b}	5.48 ± 0.47^{b}	13.5 ± 3.26^{b}
Cutting position	Apical	12.3 ± 2.1^{a}	1.8 ± 0.5^{a}	1.6 ± 0.5^{a}	2.5 ± 1.3^{a}
	Middle	25.2 ± 3.2^{b}	4.2 ± 0.84^{ab}	3.0 ± 0.6^{b}	6.6 ± 1.18^{ab}
	Basal	35.8 ± 3.7^{b}	7.25 ± 1.34^{b}	3.9 ± 1.04^{b}	14.16 ± 2.71^{b}

Means indicated by the same letter on the column are not statistically different ($P < 0.05$)

Interactive effects

Interactive effect of age of donor plant and IBA treatment

Interactive effect of age of donor plant and IBA treatment was highly significant ($P < 0.001$) only for percent rooting (Table 1). Application of IBA at a concentration of 300 ppm triggered and enhanced rooting of stem cuttings more pronounced in juvenile cuttings than mature cuttings. None of the untreated cuttings from mature donor plants rooted as there was no root formation at their basal ends after 50 days of propagation, but only some callus formation at the basal ends of cuttings which were visually observed. In juvenile cuttings maximum rooting percentage of $71.1 \pm 2.9\%$ for IBA treated cuttings while in mature IBA treated cuttings maximum rooting percentage of $24.4 \pm 2.6\%$

(Table 3). DMRT revealed that stem cuttings from juvenile donor plant treated with IBA at 300 ppm had significantly high percent rooting, root number and root length followed by cuttings from mature donor plant treated with IBA at 300 ppm (Fig. 1). Insignificant difference was revealed by DMRT for percent rooting, root number and root length in untreated cuttings from both juvenile and mature donor plant for the interaction of age of donor plant and IBA treatment (Table 3). IBA treated cuttings from mature donor plant had significant high percent callusing compared to IBA treated and untreated cuttings from juvenile donor plant (Table 3). Three way interactive effect of cutting position × IBA treatment × age of donor plant was insignificant for all rooting parameters evaluated.

Interactive effect of age of donor plant and cutting position

Interactive effect of age of donor plant and cutting position was highly significant ($P < 0.001$) for percent rooting, root number and percent callusing (Table 1). Mean separation by DMRT revealed that basal cutting position from juvenile donor plant had significantly high rooting percentage followed by the middle cutting position from also juvenile donor plant. DMRT also revealed that basal cutting position from mature donor plant was insignificant for percent rooting from middle cutting position taken from juvenile donor plant (Table 3). In terms of number of roots per cutting, basal cutting position from juvenile donor plant had significantly high root number followed by middle cutting position from the juvenile donor plant whereas root number was insignificant in all cutting positions from mature donor plant. Basal cutting position from mature donor plant had significantly high percent callusing whereas other cutting position from both juvenile and mature donor plant which were insignificant.

Interactive effect of cutting position and IBA treatment

Interactive effect of cutting position and IBA treatment was found to be highly significant ($P < 0.001$) for rooting percentage, root number and root length (Table 1). Generally all stem cutting positions treated with IBA at 300 ppm had significantly higher performance in rooting ability than untreated (IBA at 0 ppm) stem cuttings (Table 3). Means separation by DMRT showed that for cutting positions treated with IBA at 300 ppm basal cutting position had significantly highest rooting percentage and root number per cuttings and followed by the middle cutting position, whereas the apical cutting position had the lowest rooting percentage and root number. Root length and percent callusing were for cutting positions treated with IBA at 300 ppm were also significantly highest for basal cutting position followed middle cutting position and lowest for apical cutting position (Table 3). Untreated cuttings from basal, middle and apical cutting positions revealed insignificant difference for rooting percentage, root number, root length and percent callusing (Table 3).

Discussion

Effect of age of the donor plant

Stem cuttings of *D. melanoxylon* taken from juvenile donor plants rooted better than cuttings taken from mature donor plants indicating that age of donor plants is crucial for rooting. Researchers working with other species have shown that the ability to form

Table 3 Effect of two way interactions of age of age of donor × IBA treatment, age of donor × cutting position and cutting position × IBA treatment on rooting percentage, number of roots, root length and callusing percentage for *D. melanoxylon* stem cuttings

Interactive variables			Rooted cuttings (%)	No. of roots/cutting	Root length (cm)	Callused cuttings (%)
Age of donor plant × IBA treatment	Juvenile	0 ppm	5.6 ± 1.4^{a}	1.2 ± 0.4^{a}	0.8 ± 0.2^{a}	0^{a}
		300 ppm	71.1 ± 2.9^{c}	11.4 ± 1.3^{c}	6.2 ± 0.8^{c}	2.2 ± 0.4^{a}
	Mature	0 ppm	0^{a}	0^{a}	0^{a}	5.5 ± 1.4^{a}
		300 ppm	24.4 ± 2.6^{b}	5.1 ± 0.7^{b}	4.5 ± 0.4^{b}	23.3 ± 2.7^{b}
Age of donor plant × cutting position	Juvenile	Apical	23.3 ± 1.5^{ab}	2.1 ± 0.7^{a}	1.7 ± 0.5^{a}	0^{a}
		Middle	38.3 ± 1.7^{ab}	5.9 ± 0.9^{ab}	3.6 ± 1.3^{a}	1.7 ± 0.6^{a}
		Basal	53.3 ± 2.4^{b}	11.1 ± 1.2^{b}	5.2 ± 1.6^{a}	1.7 ± 0.4^{a}
	Mature	Apical	6.7 ± 1.3^{a}	1.5 ± 0.2^{a}	1.5 ± 0.7^{a}	5.2 ± 1.2^{a}
		Middle	11.7 ± 1.4^{a}	2.6 ± 0.4^{a}	2.4 ± 1.2^{a}	11.7 ± 1.7^{a}
		Basal	18.3 ± 1.6^{ab}	3.5 ± 0.5^{a}	2.7 ± 0.4^{a}	26.7 ± 2.2^{b}
Cutting position × IBA treatment	Apical	0 ppm	0^{a}	0^{a}	0^{a}	0^{a}
		300 ppm	30 ± 1.3^{b}	3.6 ± 0.8^{a}	3.3 ± 0.4^{b}	3.3 ± 1.2^{a}
	Middle	0 ppm	1.7 ± 0.2^{a}	0.5 ± 0.3^{a}	0.4 ± 0.1^{a}	1.7 ± 0.6^{a}
		300 ppm	48.3 ± 2.4^{bc}	7.9 ± 0.9^{b}	5.7 ± 0.9^{c}	11.7 ± 1.8^{ab}
	Basal	0 ppm	6.7 ± 0.7^{a}	1.3 ± 0.5^{a}	0.8 ± 0.4^{a}	5.3 ± 1.6^{a}
		300 ppm	65 ± 2.3^{c}	13.4 ± 1.2^{c}	7.1 ± 1.1^{c}	23.3 ± 2.1^{b}

Means indicated by the same letter on the column are not statistically different ($P < 0.05$)



Fig. 1 Rooting of the *D. melanoxylon*; **a** cuttings from basal position of juvenile donor plant treated with IBA; **b** cuttings from basal position of mature donor plant treated with IBA

adventitious roots on stem cuttings decreases with increasing age of donor plant (Stenvall et al. 2004; Bhardwaj and Mishra 2005; Husen and Pal 2006; Opuni-Frimpong et al. 2008). Enhanced rooting and increased vegetative vigor are typical in the juvenile phase which can improve rooting of cuttings (Tetsumura et al. 2001).

Stem cuttings taken from juvenile donor plants are generally considered easy to propagate by cuttings due to their young ontogenetic, physiological and chronological age and possibly to its low production of secondary metabolites (Husen and Pal 2006). Decrease in rooting potential of stem cuttings due to increased age of donor of the donor plants may be due to a decrease in the content of endogenous auxins or accumulation of inhibitory substances which inhibit rooting (Husen and Pal 2006; Opuni-Frimpong et al. 2008). Haissig (1989) reported deterioration in rooting ability of *Pinus banksiana* cuttings from mature donor plants compared with that of seedlings due to decreased rate of net photosynthesis and altered carbohydrate metabolism.

Effect of IBA treatment

Like many other species, rooting ability of *D. melanoxylon* was sensitive to the IBA application. Cuttings treated with IBA produced more roots as well as longer roots than untreated cuttings. Similar results were reported by Ofori et al. (1996) in which the mean number of roots per cutting was higher when the cuttings of *Milicia excelsa* were treated with IBA than untreated cuttings. The stimulatory effects of IBA in rooting of stem cuttings of several other woody plant species have been reported by other workers who have revealed that IBA has an important role in the development of adventitious roots, increasing rooting percentage, improving quality of roots and uniformity in rooting of cuttings (Negash 2002; Tchoundjeu et al. 2002; Teklehaimanot et al. 2004; Husen and Pal 2007b; Opuni-Frimpong et al. 2008). Root formation process in cuttings is intensified by

IBA which influences polysaccharide hydrolysis resulting in increased content of physiologically active sugar needed to provide energy for meristematic tissues and later for root primordia and roots formed as reported in *Tectona grandis* (Husen and Pal 2007a) and *Dalbergia sissoo* (Husen 2008).

Effect of cutting position

Differences existed terms of rooting ability of *D. melanoxylon* stem cuttings taken from different cutting positions from the shoot of donor plants. High rooting percentage, root number, root length, callus formation was observed in cuttings taken from basal positions followed by those taken from middle cutting positions. The cuttings made from apical positions had the lowest rooting ability for all rooting parameters evaluated. Variations in rooting ability between cuttings taken from different portions of the shoot have been reported (Al-Salem and Karam 2001; Husen and Pal 2007b). The findings from this study for high rooting ability of cuttings taken from the basal position are in agreement with other studies conducted for other tree species such as *Dalbergia sissoo* (Husen 2004) and *Ulmus villosa* (Bhardwaj and Mishra 2005). Better rooting of cuttings made from basal positions followed by cuttings from middle position than those made from apical positions is potentially associated with increased carbohydrate storage, initiation of preformed root primordia, and differences in organogenic activity along the stem of the parental shoot as it has been reported by other researchers (Zalesny et al. 2003).

Interactive effect of treatments

Analysis of the interactions between treatments illustrated many significant effects on rooting in *D. melanoxylon.* The significant interactive effect of age of donor and IBA treatment for percent rooting revealed that IBA treated cutting from juvenile donor plant had higher rooting percentage than IBA treated cuttings from mature donor plant. Untreated cuttings from juvenile donor plant had low rooting percentage whereas none of cuttings from mature donor plant rooted without IBA application. Rout (2006) has also found that the beneficial effects of applied IBA on rooting cuttings decreased with age of donor plant due to decreased sensitivity of aging tissues to rooting promoters. A study by Swamy et al. (2002) investigated the effect of maturity and IBA application on rooting of *Robinia pseudoacacia* found that cuttings from mature trees were not only more difficult to root, but that juvenile cuttings also responded better to IBA application. A study on the effect of IBA and juvenility on the rooting of *Rhamnus caroliniana* cuttings also found a significant interaction between the effects of IBA and age of donor plant whereby juvenile cuttings treated with IBA at 3,000 ppm, had higher rooting than mature cutting at the same IBA concentration (Graves 2002). On the other hand, significant interactions between cutting position and age of donor plant, the cutting position and IBA treatment occurred, especially regarding the rooting percentage, root number and root dry weight. The occurrence of such interactive effects between factors could be closely related to the endogenous auxin balance and the amount of carbohydrates in the cuttings and the donor plant, as it has been reported for many forest species (Smart et al. 2003; Zalesny et al. 2003). Moreover, auxin–carbohydrate interactions are also observed to be vital for rooting in Arabidopsis (Sorin et al. 2005), *Tectona grandis* (Husen and Pal 2007a) and *Dalbergia sissoo* (Husen 2008).

Callus and root nodules formation

Callus formation was more prominent in mature cuttings compared to juvenile stem cuttings of *D. melanoxylon* particularly those taken from the basal and middle positions. From the results it seems that differentiation of vascular tissue within the callus at the base of the cuttings is more likely to occur with mature cuttings which were influenced by the quality of the callus produced at the base of their cuttings than from juvenile cuttings. Some of the callus at the base of cuttings of *D. melanoxylon* differentiated into roots, thus it seems important to have a high callus formation for better rooting. Callus formation is frequently described as resulting in adventitious rooting (Dirr 1998). Nevertheless, other findings by (Hartmann and Kester 1975) reported that formation of callus and the formation of roots are independent of each other. In some species, however (e.g. *Hedera helix*), mature cuttings, adventitious roots have been found to originate from the callus tissue formed at the basal end of the cuttings (Girouard 1967). In such cases, callus formation is a precursor of adventitious rooting as it was evident in this study of *D. melanoxylon.* Bonga (1982) has attributed the non-differentiation of callus into roots could either be due to lack of sufficient food reserve and some internal factors and/or age of the cuttings. Such limitations could also be causative factors to non rooting in *D. melanoxylon*.

Root nodules formation on roots of some rooted stem cuttings of *D. melanoxylon* was evident in this study particularly from basal cutting position of juvenile donor plant. An average of 5–8 nodules per rooted cutting was observed. All three cutting positions from mature donor plant showed no root nodule development on their roots. Root nodules formation on rooted stem cuttings from juvenile donor plants as observed in this study revealed a leguminous characteristic of *D. melanoxylon* for nitrogen fixation. With such ability for nitrogen fixation, *D. melanoxylon* can be incorporated into agroforestry systems in order to improve soil fertility and enhance agricultural production. Therefore, vegetative propagation techniques can greatly contribute to future domestication trials of *D. melanoxylon* as a potential tree for poverty alleviation by generating income for poor subsistence farmers. Domestication of *D. melanoxylon* can also reduce already existing pressure by over exploitation in its natural populations. The non-mist propagator used in this study is appropriate for tropical areas as it does not require electricity or piped water and can be constructed from cheap, locally available material. The system is appropriate for small scale commercial and community reforestation projects.

Conclusion

In conclusion, the present study has revealed that the best combination of factors for vegetative propagation of *D. melanoxylon* by stem cuttings is the use of basal cutting position from juvenile donor plant treated with IBA at 300 ppm. Many poor farmers are interested in fast growing; multipurpose tree species for quick earning, therefore vegetative propagation may reduce the rotation time of *D. melanoxylon* which normally takes between 70 and 100 years from seed germination to maturity for wood harvesting. Propagation through stem cuttings will be a rapid means for mass propagation of the species and will serve as alternative to the use of seeds in *D. melanoxylon* which has poor germination. It is also recommended that *D. melanoxylon* should be incorporated into agroforestry systems in Tanzania especially where soil is known to be nitrogen deficient because of its ability for nitrogen fixation.

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