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Background

In 2000, the then Faculty of Forestry and Nature Conservation (now College of Forestry, Wildlife and Tourism) of the Sokoine University of Agriculture (SUA) in Morogoro, Tanzania, inaugurated the *Tanzania Journal of Forestry and Nature Conservation*. This development was taken in order to elevate the former publication of the then Faculty of Forestry, *Faculty of Forestry Records*, to a status of an International Journal. The last issue of the *Faculty of Forestry Records* was volume 72 and this Journal took over beginning with volume 73.

Scope

The *Tanzania Journal of Forestry and Nature Conservation* accommodates the current diverse and multidisciplinary approaches towards ecosystem conservation at national and global levels. The journal is published biannually and accepts research and review papers covering technological, physical, biological, social and economic aspects of management and conservation of tropical flora and fauna.

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ABOUT THE COLLEGE OF FORESTRY, WILDLIFE AND TOURISM

The College of Forestry, Wildlife and Tourism of SUA attained its present status in July 2017. It started in 1973 as a Division of Forestry in the Faculty of Agriculture of the University of Dar es Salaam. Thereafter, it was elevated to a Faculty of Forestry in 1984 when SUA was established. SUA is located 3 km from the centre of Morogoro Municipality, which is 200km west of Dar es Salaam, along the Tanzania-Zambia highway.

There are six departments in the College formed on the basis of specialisation: Departments of Ecosystems and Conservation, Forest Engineering, Forest Economics, Forest Mensuration and Management, Forest Products and Technology and Wildlife Management.

The Faculty maintains three training forests. The first, covering 848 ha, is located at Olmotonyi on the slopes of Mount Meru near Arusha and is devoted to plantation forest management. The second covering 320 ha is a fully protected virgin rain forest located at Mazumbai in the west Usambara Mountains devoted to montane rain forest management. The third is Kitulangh'alo forest reserve covering 500 ha located near Morogoro and devoted to the management of miombo woodlands. These forests offer practical and research venues for both students and staff.

The College offers 3 three-year undergraduate degrees namely BSc (Forestry), BSc (Wildlife Management) and Bachelor of Tourism Management. So far, these programmes have attracted students from many African countries. Post-graduate programmes: (MSc) both in Forestry and in Management of Natural Resources for Sustainable Agriculture (MNRSA) and PhD in Forestry, are also offered. These programmes are tailored to produce personnel for higher professional positions in forestry, wildlife, natural resource management, tourism management and administration including teaching and research. Graduates find employment in forestry, wildlife, tourism other environmental services in government institutions and private or non-government organizations.

Entry Qualifications for all degree programmes are detailed in the SUA prospectus, but specific information related to forestry, wildlife and tourism management programmes may be obtained from:

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Effect of rooting media and indole-3-butyric acid concentrations on regeneration potential of Elgon Olive (*Olea welwitschii* (Knobl.) Gilg & Schellenb) stem cuttings

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ABSTRACT
Elgon olive which is prized for durable structures and furniture has become rare and efforts to increase its population have been hampered by poor seed germination rates associated with dormancy. Search for alternative multiplication of the species is therefore important. The effect of rooting media and rooting hormone on regeneration potential of *O. welwitschii* were evaluated using leafy juvenile stem cuttings as an alternative multiplication method. A factorial experiment with 3 x 3 treatment combinations was established in a non-mist propagator in a complete randomized design with three replications. Factor one had three types of rooting media (fine river sand mixed with decomposed sawdust at 1:1 v/v, red clay subsoil and fine river sand) and factor two was rooting hormone indole-3-butyric acid (IBA) with three concentrations (0, 3000 and 6000 ppm). Data on rooting percentages and rooting variables were subjected to analysis of variance using SAS. The combination of fine sand mixed with decomposed sawdust media and cuttings treated with IBA at 6000 ppm provided the highest ($p < 0.05$) rooting of 92.3% and largest ($p < 0.05$) number of roots per cutting of 13.77. The combination of fine river sand mixed with decomposed sawdust and treated leafy juvenile stem cuttings with IBA at concentration of 6000 ppm is recommended as alternative technique for optimum production of *O. welwitschii* planting materials.

Keywords: Dormancy, alternative, multiplication, stem cuttings, rooting variables, optimum

INTRODUCTION
In Tanzania, the Elgon olive (*Olea welwitschii* (Knobl.) Gilg & Schellenb) grows in wetter slopes of Kilimanjaro, Meru, Uluguru, Pare, and Usambara Mountains and in the southern highlands (Mbuya *et al*. 1994; Ruffo *et al*. 1996; Shangali *et al.* 2004). The high demand for *O. welwitschii* for making durable structures and high class furniture for national and international markets has led to its protection against uncontrolled harvesting and establishment of conservation initiatives (Maundu and Tengnäs 2005; Orwa *et al.* 2009). Based on these initiatives, the tree species was recommended for plantation and agroforestry establishments (Hines and Eckman 1993; Aerts 2011).

However, efforts aimed at increasing its population through seed-based propagation have been reported to be affected by seed unavailability, poor seed germination rates and loss of viability. Seed availability of *O. welwitschii* is erratic as trees tend to produce seeds after 2 - 7 years (Orwa *et al.* 2009; Aerts 2011; ICRAF 2012). Germination rate is sporadic varying between 30% and 35% over a period of nine months and sometimes up to two years (Maundu and Tengnäs 2005; Aerts 2011). This habit of poor germination rates exists among olive species whereby total failure of germination has been reported (Nduwayezu *et al.* 2009; Tsingalia and Humphrey 2010). Seed viability is lost within 3 months after harvesting but may last longer if seeds are stored at 3^{o}C (Orwa *et al.* 2009; Aerts 2011).

Clonal propagation by stem cuttings plays an important role in multiplication and conservation of elite trees (Hae and Funnah 2011; Ujjwala *et al.* 2013). Plant vegetative parts like shoots, which are often available all year round from mother plants can serve as good sources of propagules for mass production of *O. welwitschii* seedlings. The regeneration by stem cuttings in most tree species is achieved by using suitable rooting media (Egbe *et al.* 2012; Ujjwala *et al.* 2013). Suitable rooting medium for stem cutting propagation should be low in nutrients, sterile, porous, aerated, drainable and capable of holding some amount of water (Hartmann *et al.* 2011). Rooting media with these properties include inorganic substrates such as sand, perlite and vermiculite and organic substrates like sawdust, compost, tree barks and peat moss. Depending on the tree species, these substrates have been used either alone or in mixture to improve physical properties such as water holding capacity, aeration and drainage of the media (Hartmann *et al.* 2002; Hartmann *et al.* 2011). For instance, fine sand promoted rooting of *Diospyros crassiflora* stem cuttings when used alone or mixed with decomposed sawdust (Alain *et al.* 2011).

On the other hand, the use of rooting hormones on cuttings in combination with appropriate rooting media has been reported to hasten root formation in recalcitrant plant species and indole-3-butyric acid (IBA) is mostly used (Hartmann *et al.* 2002; Hartmann *et al.* 2011). The rooting hormone concentration used depends on tree species and part of the tree used (Hartmann *et al.* 2011). For example, stem cutting rooting variables were improved when IBA concentrations at 250 ppm was used on *Azadirachta indica* (Gehlot *et al.* 2014), 3000 ppm on *O. europea* (Kurd *et al.* 2010) and 8000 ppm on *Warbugia ugandensis* (Akwatulira *et al.* 2011).

Vegetative propagation using stem cuttings may provide an alternative method for multiplying *O. welwitschii*. However, the effect of rooting media and IBA hormone concentration on regeneration of *O. welwitschii* using leafy juvenile stem cuttings is hardly known. The objective of this study was therefore to evaluate the effect of rooting media and IBA concentrations on regeneration potential of *O. welwitschii* leafy juvenile stem cuttings. The study aimed at achieving propagation technique that will enhance optimum availability of planting materials of *O. welwitschii* for plantation and agroforestry establishments.

MATERIALS AND METHODS

Study site

Seeds for establishment of stock plants were collected from Usa which is within Meru-Usa Forest Plantation in Arusha region, Tanzania. The plantation lies between latitude 3º15'-3º18'S and longitudes 36º41'-36º42'E with elevation ranging from 1,500 – 2,200 m above sea level. The area has black brown or black well drained fertile volcanic soils with pH of 5.5 - 6.5. The soil is rich in calcium, phosphorus and potassium with relatively poor level of Nitrogen (Ngaga, 2011; URT 2013). Establishment of mother plants for production of leafy juvenile stem cuttings and assessment of the regeneration potential of *O. welwitschii* were carried out at Horticulture Section nursery of Sokoine University of Agriculture (SUA) in

Morogoro Tanzania. The nursery is located at 6º50'S, 37º39'E and 504 m above sea level.

Establishment, management of mother plants and preparation of cuttings

Seeds for establishment of mother plants were collected in September 2012 and raised at Horticulture section nursery using sand as the medium. After germination, seedlings were transplanted into 30 cm diameter polythene tubes with a mixture of top forest soil, sand and cow dung manure at a ratio of 3:1:1 (v/v/v) in between December 2012 and April 2013. Seedlings of the age between 3 and 6 months with an average height of 38 cm and root collar diameter of 5.03 mm were decapitated at the height of 10 cm for axillary shoots production in August 2013 (Plate 1A). The decapitated seedlings were treated with foliar fertilizer Omex Murex K at the rate of 3ml/L and hormone 6-benzylaamino purine (BAP) at the rate of 2 mg/L to enhance coppice development (Plate 1B). After coppicing, seedlings were further treated with Volar MZ 690 WP (Dimethomorph and Mancozeb) fungicide at 3 g/L for controlling fungal diseases. Shoots from decapitated seedlings were harvested at 9 months for production of leafy juvenile stem cuttings (semi-hardwood cuttings). Cuttings of two to three nodes, 5 - 7 cm long having 1 – 2 pairs of leaves were harvested and their leaves trimmed to half size (Plate 1C) and soaked in water to protect them from desiccation and maintain their freshness. They were further cleaned with running tap water for 15 minutes, rinsed twice with distilled water and left in the third rinse until setting.

Plate 1: *Olea welwitschii* stock plants management: A – Decapitated seedlings, B - Development of axillary shoots and C - Semi-hardwood cuttings ready for planting/setting.

Collection and preparation of rooting media

Rooting media used were fine river sand (≤ 2 mm) mixed with decomposed sawdust, red clay subsoil and fine river sand. Red clay subsoil was collected from TAFORI headquarters trial site, river sand was collected from Ngerengere River and decomposed sawdust was obtained from saw mills within Morogoro municipality in Tanzania. The decomposed sawdust that was 6 years old had a mixture of various tree species such as *Afzelia quanzensis, Pterocarpus angolensis, Mangifera indica, Khaya anthotheca,* Pine species, *Cedrela odorata, Grivellea robusta* etc. All media were sterilized by solarisation at between 60 and 70^{o}C for three days (Jaenicke 1999) and sieved through 2 mm sizes before being used. Before setting up the experiment, the media were evaluated for porosity, water holding capacity and pH (Table 1). Porosity was determined by the saturation method (Matko 2003, Nimmo 2004), water content by the dry oven method (Ofori *et al.* 1996, O'Kelly and Sivakumar 2014) and pH using a pH meter (model 510, Eutech Instruments).

Red clay subsoil and fine river sand mixed with decomposed sawdust were potted in 10 cm diameter polythene pots and placed on the upper layer inside of non-mist propagator as the rooting media. In another propagator cage, a layer of about 5 cm thick of fine river sand was used directly as a rooting medium (Plate 2C). All rooting media were further disinfected with a fungicide Volar MZ 690 WP (Dimethomorph and Mancozeb) at 3g/L of water three days before setting the cuttings (Ofori *et al.* 1996). The non-mist propagator technology which was prepared according to Leakey *et al.* (1990) with modification by arranging polythene tubes inside the non-mist was adopted because of its low cost for installation and simplicity in application (Leakey *et al.* 1990, Amri 2010).

Table 1. Porosity, water content and pH of media used in regenerating *O. welwitschii* stem cuttings

Medium	Porosity (%)	Water holding capacity (%)	pH
Fine sand mixed with decomposed sawdust	23.4	34.6	6.1
Red clay subsoil	26.7	31.3	5.9
Fine sand	39.3	28.6	7.8

Experimental design and management

A factorial experiment with 3 x 3 treatment combinations was arranged in a complete randomized design with three replications. Three categories of rooting media factor namely fine sand mixed with decomposed sawdust at the ratio of 1:1 (v/v), red clay subsoil and fine river sand alone were used. The rooting hormone factor (IBA in powder form) was applied at three concentration levels of 0 as control, 3000 and 6000 ppm. Each replicate consisted of 13 stem cuttings making a total 351 for the whole experiment.

Bases of the cuttings were dipped in rooting powder IBA Hormoril 6 GADOT Agro product at a depth of 5 mm and the excess powder was removed by tapping off before setting them in the propagator. A portion of the prepared cuttings was set in polythene tubes (10 x 12 cm) filled with red clay subsoil media and sand mixed with decomposed sawdust (Plate 2A and 2B) respectively while the remaining portion was set directly in the fine river sand media (Plate 2C). The propagator cages were kept under a shade house to reduce temperatures (Plate 2D). Water was maintained at the bottom layer of the propagator cages for sub-irrigation, raising and maintaining relative humidity (RH) and temperature. Relative humidity was maintained at 90±10% while minimum and maximum temperatures were 22±2 and 30 ± 2^{0}C, respectively. The relative humidity and temperatures were recorded using digital Hygro-thermometer TH 550 Dickson instruments

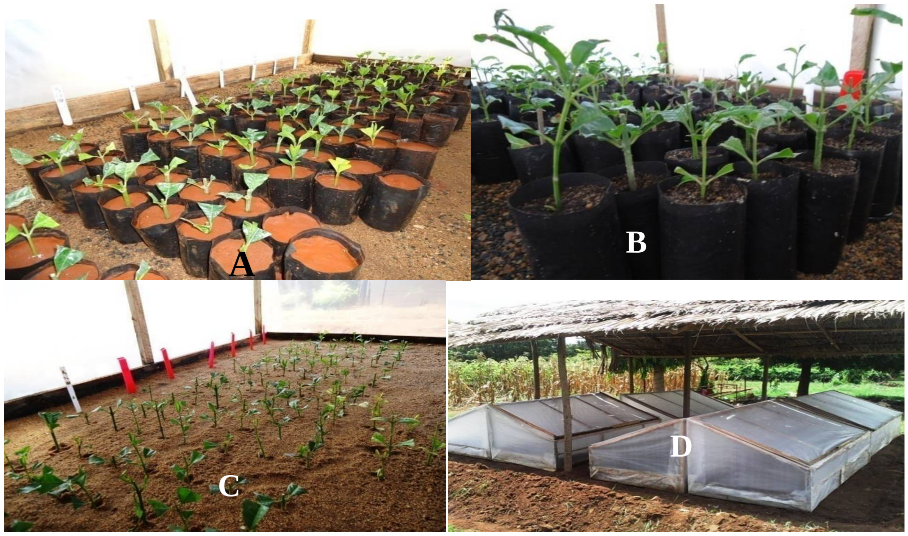

Plate 2: *Olea welwitschii* stem cuttings setting: A - cuttings set in polythene tubes with red clay subsoil medium, B - cuttings set in polythene tubes with sand mixed with decomposed sawdust, C - cuttings set directly in sand medium, and D - non-mist propagators' cages in a shade house.

DATA COLLECTION

Cuttings were initially assessed for root formation 30 days from the date of setting and later at an interval of 15 days until when all cuttings had either rooted or died. A cutting was regarded as rooted when it had at least one root greater than one mm long (Amri *et al.* 2009). The regeneration potential of the stem cuttings was scored based on the number of cuttings that had formed callus and roots, number of roots per stem cutting, root length and diameter (Plate 3). Root length was measured with a ruler from the point of emergence to the tip while root diameter was measured at root base with digital caliper.

Plate 3: Leafy juvenile stem cuttings of *O. welwitschii*: A – uncallused stem cuttings, B – callused stem cuttings, C - rooted stem cuttings set in red clay subsoil and D – rooted stem cuttings set in river sand mixed with decomposed sawdust.

The rooted cuttings were transplanted into growing media with a mixture of top forest soil, sand and decomposed cow dung manure at a ratio of 3:1:1 (v/v/v) potted in 10 x 12 cm black polythene tubes. The cuttings were kept in the non-mist propagator cages for 7 days and thereafter in a lathe house for 14 days (Plate 4A and 4B) respectively for acclimatization before they were reared in high plastic tunnel (Plate 4C and D). In order to maintain one healthier single shoot, both in the lathe house and high plastic tunnel, multiple shoots from cuttings were pruned using secateurs.

Plate 4: Regenerated seedlings of *O. welwitschii*: A and B - seedlings in non-mist propagator and lathe house respectively for acclimatization, C and D - some of 8 months old seedlings under the plastic tunnel ready for field transplanting.

DATA ANALYSIS

Rooting variables and arcsine-transformed percentage data were subjected to analysis of variance (ANOVA) using SAS version 9.1 for windows (SAS Institute inc. 2002) to determine the optimal combination of rooting hormone and media. Separation of significance difference between treatments means were done using Duncan Multiple Range Test (DRMT) at probability level of 5%.

RESULTS

Effects of rooting media on regeneration of *O. welwitschii* leafy juvenile stem cuttings

Rooting media had a significant ($p = 0.0011$) effect on percentages of callused stem cuttings, significant ($p < 0.0001$) effect on percentage of rooted cuttings, number of roots per stem cutting and root length (Table 2). Fine sand mixed with decomposed sawdust and red clay subsoil resulted in the highest callus formation of 53.0 and 58.15%, rooting of 80.31 and 78.62% and number of roots per cutting of 12.4 and 10.1, respectively compared to fine river sand alone. However, stem cuttings in fine river sand mixed with decomposed sawdust media produced significantly ($p = 0.0001$) the longest roots with 1.57 cm compared with red clay subsoil and fine river sand alone with root length of 1.0 and 0.93 cm, respectively.

Table 2. Effect of rooting media on rooting variables of *O. welwitschii* leafy juvenile stem cuttings

Rooting media	Percentage of callused stem cuttings	Percentage of rooted stem cuttings	Number of roots per cutting	Root length (cm)	Root diameter (mm)
Fine sand mixed with decomposed sawdust	53.00[a]	80.31[a]	12.43[a]	1.57[a]	0.61
Red clay subsoil	58.15[a]	78.62[a]	10.11[a]	1.00[b]	0.60
Fine sand alone	16.23[b]	5.15[b]	3.90[b]	0.93[b]	0.59
p-value	0.0011	< 0.0001	< 0.0001	<0 .0001	ns

Numbers bearing the same letter within a column are insignificantly (p < 0.05) different based on DMRT.

Effects of IBA concentrations on regeneration of *O. welwitschii* leafy juvenile stem cuttings

Indole-3-butyric acid concentrations significantly (p = 0.0054) improved the percentage of callused stem cuttings, (p <0.0001), the number of roots per stem cutting, root length and root diameter in comparison to the control (Table 3). Indole-3-butyric acid at 6000 ppm resulted significantly in the highest callus formation of 55.54%, rooting of 59.84% and number of roots per stem cutting of 12.54 compared with IBA applied at 3000 ppm and the control. The longest root (1.6 mm) was produced on cuttings treated with IBA at 3000 ppm while root with bigger root diameter (0.66 mm) was from untreated cuttings (control).

Table 3. Effect of Indole-3-butyric concentrations on regeneration of *O. welwitschii* leafy juvenile stem cuttings

IBA concentration (ppm)	Percentage of stem cuttings callused	Percentage of stem cuttings rooted	Number of roots per cutting	Root length (cm)	Root diameter (mm)
Control (0)	20.54[b]	47.85	9.84[c]	1.09[c]	0.66[a]
3000	51.31[a]	56.38	11.22[b]	1.60[a]	0.58[b]
6000	55.54[a]	59.84	12.54[a]	1.25[b]	0.58[b]
p-value	0.0054	ns	<0 .0001	<0 .0001	<0 .0001

Numbers bearing the same letter within a column are insignificantly (p < 0.05) different based on DMRT.

Interactive effect of rooting media and IBA concentration on regeneration of *O. welwitschii* leafy juvenile stem cuttings

The interaction of rooting media and IBA concentrations had a significant (p < 0.0001) effect on the number of roots per stem cutting (Table 4). Stem cuttings treated with IBA at 6000 and 3000 ppm and planted in river sand mixed with decomposed sawdust attained the largest number of roots per stem cutting of 13.77 and 13.13, respectively, IBA at 6000 ppm resulting into highest number of roots (13.77) and rooting of 92.3%.

Table 4. Interactive of effect rooting media and hormone concentration on regeneration variables for *O. welwitschii* leafy juvenile stem cuttings

Rooting Media x Rooting hormone IBA (ppm)	Callusing (%)	Rooting (%)	Number of roots per stem cutting	Root length (cm)	Root diameter (mm)
Sand mixed with decomposed sawdust x control (IBA at 0)	33.33	69.23	9.11[c]	1.36	0.68
Sand mixed with decomposed sawdust x IBA at 3000	56.41	74.36	13.13[a]	1.88	0.60
Sand mixed with decomposed sawdust x IBA at 6000	69.23	92.31	13.77[a]	1.44	0.58
Clay red subsoil x control (IBA at 0)	25.64	71.79	8.52[c]	0.91	0.65
Clay red subsoil x IBA at 3000	76.92	89.74	10.55[b]	1.19	0.54
Clay red subsoil x IBA at 6000	87.18	76.92	10.87[b]	0.96	0.57
Fine sand x control (IBA at 0)	2.56	2.56	5.10[d]	0.74	0.72
Fine sand x IBA at 3000	23.08	5.13	3.00[e]	1.07	0.58
Fine sand x IBA at 6000	23.08	7.69	2.33[f]	1.18	0.38
p - value	ns	ns	<0.0001	ns	ns

Numbers bearing the same letter within a column are insignificantly ($p < 0.05$) different based on DMRT.

DISCUSSION

Effects of rooting media on regeneration of *O. welwitschii* leafy juvenile stem cuttings

Result of the study indicate that, fine river sand mixed with decomposed sawdust and clay red subsoil media improved the rooting variables of *O. welwitschii* leafy juvenile stem cuttings compared to fine river sand media alone. The improved rooting variables in this study using the above media was contributed by good aeration, moderate water holding capacity and suitable pH levels (Table 1). Similar performance on the use of sand mixed with decomposed sawdust medium was reported also in stem cuttings of *Milicia excelsa* (Ofori *et al.* 1996) and *Diospyros crassiflora* (Alain *et al.* 2011). Findings from other studies show that, a good rooting media should have a good proportion of sand for reasonable water holding capacity and considerable level of porosity (Amri *et al.* 2009, Takousting *et al.* 2014). According to Hartmann *et al.* (2011) porosity of 15 - 40% and water holding capacity of 20 - 60 % of the media is required for optimal rooting and seedling growth. Adequate aeration at the base of cuttings enhances gaseous exchange and constant supply of oxygen for respiration and release of carbon dioxide (Raviv *et al.* 2002).

The results show that, the effectiveness of the rooting media was also influenced by aeration, water content and pH. Fine river sand mixed with decomposed sawdust and clay red subsoil media had the best combination of these factors. The pH of 6.1 and 5.9 found in fine river sand mixed with decomposed sawdust and clay red subsoil media respectively is within the favourable range of 5.5 to 6.5 from where the tree is growing in nature (Ngaga 2011, URT 2013) and that of 5.5 to 7.0 where most plants grow (Hartmann *et al.* 2011). This is the range where both macro and micro nutrients are made available to enhance rooting and growth of cuttings due to the presence of organic compound from the decomposed sawdust and clay red subsoil. Thus, depending on the sensitivity of the plant species, the pH level in the media may interfere with auxins and nutrients uptake (Giroux *et al.* 1999, Jaenicke 1999) which might have significant effect on rooting. For instance, the number of roots produced per rooted cutting of *Redvein enkianthus* was twice in a 1:8 mixture of peat to perlite with the pH of 5.2 than in perlite alone with the pH of 7.3 (Giroux *et al.* 1999). This indicates that, for successful rooting of cuttings in vegetative propagation, the pH media should be in a range similar to where the donor plant is growing.

Effects of IBA concentrations on regeneration of *O. welwitschii* leafy juvenile stem cuttings

The use of IBA at concentration of 6000 and 3000 ppm in this study promoted callusing, rooting percentage and number of roots of leafy juvenile stem cuttings of *O. welwitschii* which are important factors for regeneration through cuttings and prerequisite for seedlings establishment in the field. Treatments of cuttings with rooting hormones improve the survival and rooting of stem cuttings as well as growth of the sprouts (Hassanein 2013) because it improves enzymes activities and increasing starch hydrolysis and mobilization (Amri 2011, Kebede *et al.* 2013). The applied rooting hormone is transported to the damaged parts of cuttings where it promotes production of callus as the healing mechanism and consequently roots development (Kurd *et al.* 2010, Akwatulira *et al.* 2011). Similar effects of IBA in improving rooting variables were reported at 3000 to 4000 ppm on stem cuttings of *Olea europea* (Kurd *et al.* 2010), at 3000 ppm on *Ligustrum ovalifolium* (Hammol *et al.* 2013) and at 6000 – 8000 ppm on *Shorea parvifolia* and *S. macroptera* (Aminah *et al.* 2006). Such variations in rooting hormone concentrations and their effects on rooting depends on the tree species, provenance, age and tree part used (Dhuria 2007, Amri *et al.* 2009, Hartmann *et al.* 2011). In this study, higher concentration of rooting hormone IBA at 6000 ppm to *O. welwitschii* cuttings contributed to higher root percentages compared to other treatments combinations investigated in this study.

Interactive effect of rooting media and IBA concentration on regeneration of *O. welwitschii* leafy juvenile stem cuttings

The combination of sand mixed with decomposed sawdust media and stem cuttings treated with IBA at 6000 ppm and that of red clay subsoil and at 3000 ppm improved regeneration of *O. welwitschii* leafy juvenile stem cuttings by attaining the highest number of roots and rooting percentages compared to other treatment combinations investigated in this study. These findings have the potential of increasing seedlings production of *O. welwitschii* in Tanzania than using seeds, which at present their germination reported to be sporadic with a relatively low germination percentage. Normal or average germination rates of *O. welwitschii* seeds were reported to be 35% which can be achieved over a 9 months period and sometimes up to 2 years (Maundu and Tengnäs 2005, Aerts 2011). However among of several rooting requirements, depending on the tree species and age, successful rooting in vegetative propagation has been achieved with different combinations and thus there is no universal rooting media and hormone concentration for all tree species (Hartmann *et al.* 2011). For instance, the use of milled pine bark and IBA at 8000 ppm improved the rooting of *W. ugandensis* cuttings (Akwatulira *et al.* 2011), while when IBA at 3000 ppm was used with decomposed sawdust alone or mixed with river sand improved rooting of *D. crassiflora* twig cuttings (Alain *et al.* 2011).

CONCLUSIONS AND RECOMMENDATIONS

This study concludes that the use of fine river sand mixed with decomposed sawdust media and rooting hormone IBA at 6000 ppm in the non-mist propagator improved rooting of leafy juvenile stem cutting by 92.3% and number of roots per stem cutting by 13.77. Similarity the use clay red subsoil media and rooting hormone IBA at 3000 ppm improved rooting by 89.7% and number of roots per stem cutting by 13.13. Thus, the combination of fine river sand mixed with decomposed sawdust and leafy juvenile stem cuttings treated with 6000 ppm IBA are recommended as alternative techniques for optimum production of *O. welwitschii* planting materials. Alternatively, clay red subsoil media and rooting hormone IBA at 3000 ppm can be used as the second option. Therefore, these findings provide an opportunity for optimum multiplication of planting materials and conservation of *O. welwitschii* which currently is hampered by poor and erratic seed germination. It is the quickest approach since one seedling maintained as stock plant can produce several stem cuttings for seedlings production in a year. The research techniques from this study can also be used as basis for studying stem cutting propagation of other indigenous and exotic tree species with seed related problems for tree improvement and meeting seedling demands. However, there is a need to explore the effect of IBA concentration above 6000 ppm in order ascertain whether there is further regeneration improvement or not of *O. welwitschii* using leafy juvenile stem cuttings.

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