The Influence of Growth Regulators and Type of Cuttings on Sprouting and Rooting of *Commiphora swynnertonii* (Burrt.) and *Synadenium glaucescens* (Pax.)

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Abstract

Vegetative propagation through stem cuttings is useful for threatened plant species with abnormal flowering and fruiting behaviors, poor abilities to germinate, formulate seedlings or regenerate. This research investigates the impact of growth regulators on sprouting and rooting of C. swynnertonii and S. glaucescens. A Randomized Complete Block Design (RCBD) with 3 replications was used. The experiment involved 2 plant species; C. swynnertonii and S. glaucescens, 3 cutting types; softwood, semi-hardwood, and hardwood. Each cutting had a length of 25 cm to 30 cm. Two plant growth regulators (PGR); 1-Naphthaleneacetic acid (NAA) and Indole-3-acetic acid (IAA) were applied. Application of growth regulators NAA and IAA resulted into the tallest shoots (>100cm) from softwood, hardwood and semi hardwood types of cuttings of C. Sywnnertonii. Shoots from softwood and semi hardwood types of cuttings of S. glaucescens which were treated with NAA attained shoot length of 45 cm while the rest gave the shortest shoots of less than 40 cm. The use of NAA and IAA on softwood cuttings of S. glaucescens resulted into equally the highest rooting efficiency of 98% and 95% respectively. However, the same plant growth regulators NAA and IAA applied on semi hardwood cutting of C. sywnnertonii resulted in 60% and 30 % rooting respectively. Effects of growth regulators on both shoot and root formation was significantly dependent on plant species and environmental conditions. Therefore, we recommend a similar study to be carried out under different conditions to verify the results before recommending commercial cultivation using these treatments.

Keywords: Conservation, germination, Indole-3-Acetic Acid (IAA) and Naphthalene Acetic Acid (NAA).

Introduction

Due to an increasing global preference for herbal oriented medicine and pesticides, there is a considerable demand for the cultivation of economically significant medicinal and aromatic plants (MAPs) (Khan & Ahmad, 2019). With rising demand for pharmaceuticals and pesticides made from plants, there is a population loss in medicinal plants (Chen *et al*., 2016). Little is known about wild medicinal plants (Grigoriadou *et al*., 2019) including *Commiphora swynnertonii* (Burrt.) and *Synadenium glaucescens* (Pax.). Therefore, it is unavoidable that regeneration protocols and conservation measures for MAP species with significant commercial potential will need to be developed and put into practice very away. Since the majority of the pharmaceutical industry rely on plants for the creation of pharmacological combinations, medicinal plants are of considerable interest to researchers. *Commiphora swynnertonii* (Burrt.) and *Synadenium glaucescens* (Pax.) fall into the high-demand plants for their medicinal and pesticidal values.

Over the years, practitioners in tradition madicine have been using *C. sywnnertonii* and *Synadenium glaucescens* (Pax.) ethnomedically to treat diseases caused by bacteria, fungi, viral, inflammation and cancer, cuts and wounds

(Anand *et al.*, 2019; Gumisiriza *et al.*, 2021; Khan & Ahmad, 2019; Msengwa *et al.*, 2023; Ochollah *et al.*, 2022; Tugume *et al.*, 2016; Tugume *et al.*, 2019; Tugume & Nyakoojo, 2019; Wode *et al.*, 2019). The secondary metabolites associated with antimicrobial activities in Commiphora and Synadenium species such as terpenoids, flavonoid, steroids, sugars, and lignans do not have only medicinal value but also are good pesticides (Mabiki *et al.*, 2013; Madege *et al.*, 2023; Matendo Rehema *et al.*, 2019). Various compounds with great medicinal and pesticidal potentials have been extracted and characterized making the two plant species a potential new pharmaceutical and pesticidal crops worth being cultivated in open fields (Canter *et al.*, 2005; Jäger & van Staden, 2000).

The cultivation of medicinal plants is the most effective way of addressing the gap between supply and demand for these high value plant species. Various propagation techniques have been investigated in an attempt to develop simple but efficient technologies for mass propagation of medicinal and aromatic plants (Amujoyegbe *et al.*, 2012; Canter *et al.*, 2005; Farag & Kayser, 2015; Jäger & van Staden, 2000). Among these, are micropropagation using tissue culture techniques (Hajare *et al.*, 2021; Máthé *et al.*, 2015; Shekhawat *et al.*, 2015) but adoption of this technology has been hampered by the cost of production. Propagation using true seeds although can effectively increase medicinal plant diversity, the seeds are difficult to germinate due to seed dormancy (Han *et al.*, 2018; Laghmouchi *et al.*, 2017). Vegetative propagation using cuttings has been proved effective for many types of plants although many trees suffer from low sprouting rate due to axillary bud dormancy (Shekhawat & Manokari, 2016). Type of cutting is a known factor affecting sprouting and rooting efficiency (Shekhawat & Manokari, 2016). This paper is presenting findings of the study to find out the effects of type of cutting and plant growth regulators on the sprouting and rooting of *C. sywnnertonii* and *S. glaucescens.*

Materials and Methods

Preparation of materials

The experiment was conducted in the screenhouse at the Department of Crop Science and Horticulture of the Sokoine University of Agriculture (SUA) Morogoro, Tanzania. Stem cuttings of *C. swynnertonii* were harvested from Mererani ward in Simanjiro District of Manyara Region (3°34.5′ S, 37°0′ E at 1 009 m a.s.l). The stem cuttings of *S. glaucescens* were harvested within premises of Edward Moringe Campus of Sokoine University of Agriculture, Morogoro, Tanzania (6°85′ S, 37°65′ E at 556 m a.s.l). To confirm the plant species a botanist was involved for identification. Growth regulators; 1-Naphthaleneacetic acid (NAA,) and Indole-3-acetic acid (IAA), were purchased from Jakovic General Supplies Ltd, Morogoro, Tanzania. Propagation was done in potted steam sterilized soil-based growth media. The medium was prepared from forest soil, farmyard manure, and rice husks at a 4:2:1 ratios respectively (Mabizela *et al.*, 2017). A forest soil was collected from the Uluguru mountain forest air dried and sieved through 2mm mesh to remove clogs and stubbles. Rice husks were collected from nearby rice mills while farm yard manure was collected for SUA animal farm. To have a sterilized media, 54 autoclave bags were prepared and each filled with 5kg of soil media. To eliminate pests like fungi, bacteria, nematodes, insects and weed seeds, the media contained in autoclave bags were subjected to autoclave steam sterilization at 121°C for 25 minutes at 15 psi (Washa *et al.*, 2012). The temperature and pressure conditions were standardized since most of the target pests cannot survive a temperature beyond 70-80°C (Usman & Fatima, 2013). The steam sterilized media were immediately cooled down and a five-litre plastic pot was filled with 5kg growth media.

Experimental design

Cuttings were used to propagate the test plants, mostly following standardized instructions (Pandey *et al.*, 2012). For each plant species, three cutting types; softwood, semi-hardwood, and hardwood were taken at a length of 25 to 30 cm. Two plant growth hormones, 1-Naphthaleneacetic acid (NAA;

Merck-Sigma Aldrich, cat. no N0640) and Indole-3-acetic acid (IAA; Cambridge Isotope Laboratories, cat. no. CLM-1896), were applied to the lower end of cuttings by dipping in a 2000 ppm solution. The media and in each 10 cuttings were planted making a total of 360 cuttings from each plant species. Stem cuttings were planted at 15 cm depth. Cuttings which were not treated with plant growth regulators were considered as control. The experiment was arranged in a 3 x 3 factorial in Randomized Complete Block Design (RCBD) with four replications. The containers were placed in the screen house and watered after every two days.

Data collection

After four months of planting, all data were collected using established protocol (Diwakar *et al.,* 2011) with a few modifications. By counting the number of days since planting, the number of days it took for each treatment to sprout was recorded. Number of sprouts produced by each cutting was counted. Using measuring tape, the length of the longest sprout per cutting was calculated from the point of sprout initiation to the growing point. Each treatment's longest sprout's total number of leaves was counted. By counting the roots in each rooted cutting and calculating the average number of roots, information on the number of roots per cutting was collected. Using measuring tape, the length of the longest root per cutting was measured from the root's starting point to its growing tip. The total number of rooted (equation 1) and sprouted cuttings (equation 2) from each treatment was counted and their percentage were computed as follows;

$$Rooting = \frac{Number\ of\ cuttings\ rooed}{Total\ Number\ of\ Cuttings\ planted} x100 \text{ ..(1)}$$

$$Cutting\ survival = \frac{Number\ of\ cuttings\ survived}{Total\ number\ of\ cuttings\ planted} x100 \text{ ..(2)}$$

Data Analysis

Before analysis the data were checked for normality and later square-root transformation was done for the number of days taken to sprouting, number of sprouts per cutting, shoot length, leaves per cutting, roots per cutting, root length and seedling survival. All the data were subjected to analysis of variance using GenStat software 15th Edition (VSN International Ltd. UK). Treatment means were separated by Tukey's HSD (honestly significant difference) test at $p \leq 0.05$.

Results and Discussion

Plant species, growth regulators and cutting type shoot development

Table 1 shows that, there were significant differences between the two plant species; *C. sywnnertonii* and *S. glaucescens* in the number of days to sprouting (p<0.0001) where by *S. glaucescens* sprouted three days earlier than *C. sywnnertonii.* However, the number of sprouts per cutting produced by *S. glaucescens* was significantly lower (p<0.0002) than those produced by *C. sywnnertonii.* Similarly, statistical differences were observed between the two plant species in shoot length (p<0.0001), and leaves per cutting (p<0.0001) where by shoot length and the number leaves per cutting produced by *C. sywnnertonii* were both two time higher than those produced by *S. glaucescens.*

It was also established (Table 1) that the influence of type of cutting on number of days to sprouting, number of sprouts produced by cutting and the shoot length was significant (p<0.05) but the treatment had no significant effects on number of leaves produced per shoot (p=0.7737). Hardwood cuttings delayed sprouting by three days when compared by softwood and semi hardwood cuttings. Number of spouts varied in the order of softwood<semi hardwood<Hardwood while shoot length was highest semi hardwood followed by hardwood and lowest in softwood. Significant effects of growth regulators on days to sprouting (p=0.0038), shoot length (p=<0.0001) and number of leaves per shoot (p=0.0060) were noted. The growth regulators had no significant influence of number of sprouts (p=0.8642). Indole acetic acid (IAA) reduced the number of days sprouting of the cuttings by three days compared to the untreated (control) cuttings. The cuttings treated with 1-Naphthaleneacetic acid (NAA) had the shoot length that was two times higher than the same in untreated cuttings while the cutting that were treated with IAA had shoot length that was lower by 32cm. Similarly, with NAA treatment, the cuttings produced the

Table 1: Effects of plant genotype, cutting type and plant growth regulators on shoot sprouting

Source of variation	Days to sprout	Sprouts/cutting	Shoot length	Leaves/ cutting
COM	14.42a	4.57a	74.32a	62.81a
SYNA	11.03b	3.79b	32.25b	24.92b
p-value	***<.0001***	***0.0002***	***<.0001***	***<.0001***
H	14.75a	5.34a	57.25a	44.54
S	11.25b	3.20c	42.42b	40.54
SH	12.17b	4.00b	60.19a	46.50
p-value	0.0002	< 0.0001	0.0009	0.7737
C	14.29a	4.25	38.482a	33.38c
IAA	11.54b	4.16	47.338b	38.21b
NAA	12.33b	4.12	74.048c	60.00a
p-value	0.0038	0.8642	<0.0001	0.0060

highest number of shoots per cuttings.

Plant species and Cutting type interaction

The findings established that the interaction of plant species and type of cuttings had no significant effects on number of days to sprouting (Fig. 1A). However, there was sufficient evidence that the influence of plant species on number of sprouts per cutting, shoot length and number of sprouts per cutting was significantly dependent on the type of cutting used. *Synadenium glaucescens* propagated using hardwood cuttings gave the highest (5.12) sprouts per cutting followed by *Commiphora sywnnertonii* that was propagated using semi hardwood (4.02) (Fig.1B). Longest shoots were observed on *Commiphora sywnnertonii* propagated using semi hardwood cuttings (82.33cm) which was half (41.65cm) the length of shoots produced by *Synadenium glaucescens* propagated through the same type of cuttings (Fig. 1C). In Fig. 1D, the post hoc test showed that within plant species, the influence of type of plant on number of leaves per cutting did not vary by type of cutting. For all types of cutting, the highest number (45.45–59.78) of leaves per cutting was recorded on *Commiphora sywnnertonii* and lowest (20.21-22.34) on *Synadenium glaucescens.*

Plant species and growth regulators interaction

The study could not establish signifying interaction of type of plant and plant growth regulator as the influence days to sprouting and number of sprouts per cutting. The analysis presented in Fig. 1 C and D provide sufficient evidence that the influence of plant species on shoot length and number of leaves per cutting was dependent on the type of plant growth regulator used to treat the cuttings before planting them. Shoot lengths of 110.13cm, 90.55cm and 67.88cm were recorded for shoots produced by cuttings of *Commiphora sywnnertonii* which were treated with NAA, IAA and distilled water respectively. Shoot lengths of 40.67cm and 38.34cm were recorded in cuttings of *Synadenium glaucescens* treated with IAA and NAA and the difference was not significant but the length was significantly different from the control

Cutting type and Growth regulators interaction

This study established that the influence of type of cuttings on days to sprouting and number of leaves per cutting was no dependent on the type plant growth regulators (Fig. 3A, D). Significant influence of such interactions was observed on number of sprouts per cutting and the sprout length (Fig. 3B, C). Longest sprouts of more than 80cm were observed for semi hardwood and hardwood cuttings treated with

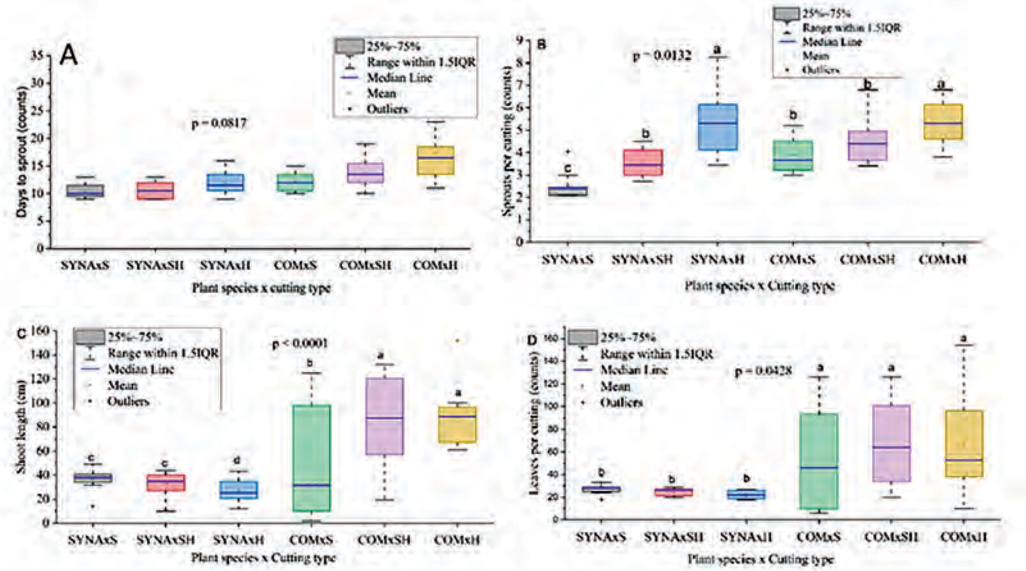

Figure 1: **Influence of two-way interaction of plant species and type of cutting used for propagation on days to sprouting (A), Sprouts per cutting (B), Shoot length (C), and Leaves per cutting (D). SYNA=*S. glaucescens* COM=*C. sywnnertonii*, S = Softwood, SH = semi hardwood, and H = hardwood. Means in the box plots headed by the same letters are not significantly different at α = 0.05.**

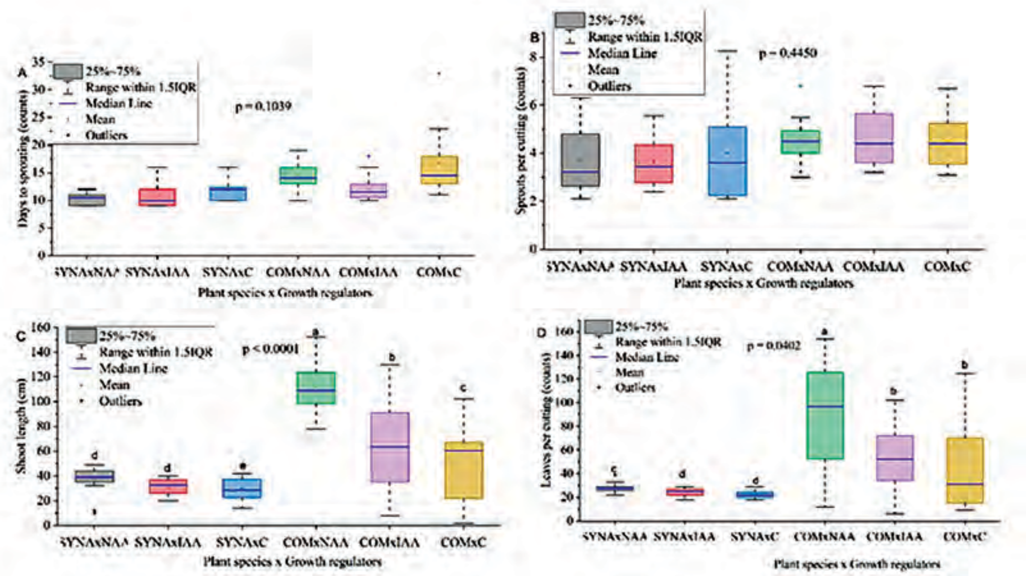

Figure 2: **Influence of two-way interaction of plant species and type growth regulator used for propagation on days to sprouting (A), Sprouts per cutting (B), Shoot length (C), and Leaves per cutting (D). SYNA=*S. glaucescens* COM = *C. sywnnertonii*, NAA =1-Naphthaleneacetic acid, IAA = Indole acetic acid, and C=Control (distilled water). Means in the box plots headed by the same letters are not significantly different at α = 0.05**

NAA and shortest sprouts of less than 30cm were observed for softwood cutting treated with IAA and distilled water (Fig. 3C). Also, the hardwood cuttings treated with distilled water produced the highest number of sprouts per cutting followed by the hardwood treated with IAA (Fig. 3B) achieved without any plant growth regulator being applied on hardwood type of cutting of *S. glaucescens* (Fig. 4B). Poorest record of less than three sprouts per cutting was with softwood cuttings of both *C. sywnnertonii* and *S. glaucescens* treated with NAA (Fig. 4B). Application of growth regulators resulted into

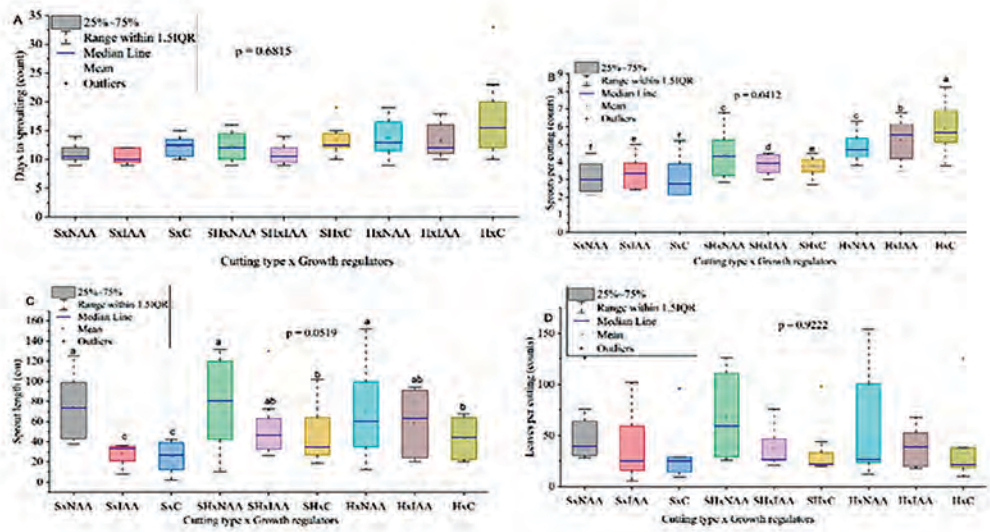

Figure 3: Influence of two-way interaction of type of cutting and type growth regulator used for propagation on days to sprouting (A), Sprouts per cutting (B), Shoot length (C), and Leaves per cutting (D). S=Softwood, SH=semi hardwood, and H=hardwood, NAA=1-Naphthaleneacetic acid, IAA = Indole acetic acid, and C=Control (distilled water). Means in the box plots headed by the same letters are not significantly different at α = 0.05.

Interaction of plant species, cutting type and growth regulators

Results in Fig. 4 presents findings regarding the influence of a three-way interaction of plant species, type of cutting and plant growth regulator on days to sprouting, sprouts per cutting, sprout length and number of sprouts per cutting. In Fig 4A and D, the finding show that the interaction of the three factors had no significant influence on the measured parameters. Figure 4B and C show that the effect of plant growth regulators on number of sprouts of each cutting and the average shoot length varied with type of cutting as well as the type of the plant. More than 6 sprouts per cutting was the highest record observed when NAA was applied on semi hardwood type of cutting of *C. sywnnertonii*. The same record was the tallest shoots (>100cm) from softwood, hardwood and semi hardwood types of cuttings of *C. sywnnertonii* dipped into both NAA and IAA (Fig. 4C). Shoots from softwood and semi hardwood types of cuttings of *S. glaucescens* which were treated with NAA attained shoot length of 45cm while the rest gave the shortest shoots of less than 40cm.

Effects of plant species, growth regulators and cutting type on root development

The number of roots per cutting varied significantly between plant species and type cuttings ($p<0.0001$) as well as type of plant growth regulator ($p = 0.0007$) (Table 2). Number of roots due to *S. glaucescens* was 30 times higher than the same due to *C. sywnnertonii*. More than 24 roots were produced due to the

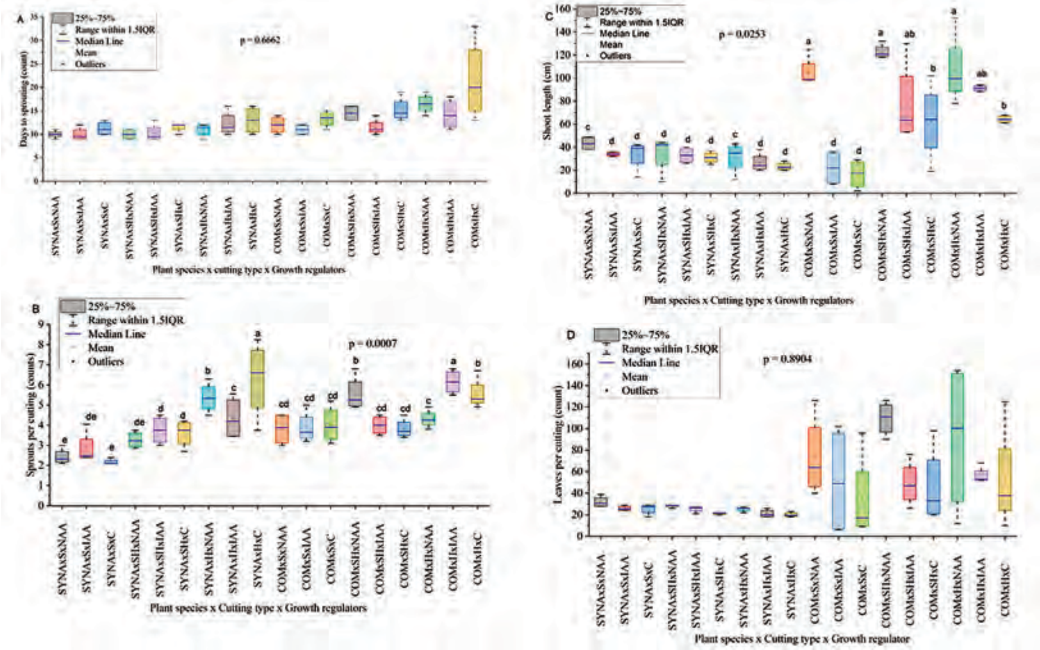

Figure 4: Influence of three-way interaction of plant species, type of cutting and type growth regulator used for propagation on days to sprouting (A), Sprouts per cutting (B), Shoot length (C), and Leaves per cutting (D). SYNA=*S. glaucescens* COM=*C. sywnnertonii,* S=Softwood, SH=semi hardwood, and H=hardwood, NAA =1-Naphthaleneacetic acid, IAA=Indole acetic acid, and C=Control (distilled water). Means in the box plots headed by the same letters are not significantly different at α = 0.05

use of hardwood type of cutting while more than 21 roots were associated with the use of plant growth regulators. Type of plant, cutting and plant growth regulator had not significant effects on root length although the same factors had substantial influence of the rooting percent and the plantlet survival. Both rooting percent and plant let survival due to *C. sywnnertonii* were three times lower than the same due to *S. glaucescens*. The use of hardwood cuttings resulted into lowest rooting (28.92%) and survival (25.58%) (Table 2). Average percent

Table 2: Effects of plant genotype, cutting type and plant growth regulators on root formation

Source of variation	Roots/cutting	Root length	Rooting %	Survival (%)
COM	1.99a	31.00	20.39a	18.44a
SYNA	32.76b	23.53	65.83b	62.78b
p-value	<.0001	0.1527	<.0001	<.0001
H	24.23a	26.75	28.92a	25.58a
S	13.38b	22.04	49.17b	48.75b
SH	14.53b	33.000	51.25b	47.50b
p-value	<.0001	0.2282	<.0001	<.0001
C	16.52a	19.33	35.42a	31.67a
IAA	14.36a	28.10	44.17b	42.08b
NAA	21.26b	34.35	49.75c	48.08c
p-value	0.0007	0.0659	0.0010	0.0001

of Rooting and survival due to the use of plant growth regulator increased in the order of Control<IAA<NAA (Table 2).

Effects of plant species and Cutting type interaction on root development

Figure 5 show that the influence of the type cutting on number of roots per cutting, root length, rooting percent and plantlet survival varied with the type of plant ($p<0.01$). For all types of cuttings, average number of roots was higher in *S. glaucescens* than *C. sywnnertonii*. More than 45 roots per cutting was recorded when Harwood cuttings of *S. glaucescens* while lowest (<2) was due to softwood of C. sywnnertonii (Fig. 5A). Close to 40cm root length was the highest record when harwood type of cutting was used to propagate *C. sywnnertonii* (Fig. 5B). Highest rooting percent of more than 9 in every 10 cuttings was attained when softwood cutting of *S. glaucescens* was used while only 1 in 10 cuttings rooted due to the use of softwood cutting of *C. sywnnertonii* (Fig 5C). Similar result as in Fig. 5C were observed for plantlet survival in Fig. 5D.

Effects of plant species and growth regulators interaction on root development

No significant statistical evidence could be established to show that the interaction between type of plant and plant growth had significant effects ($p=0.3398$) of root length of the produced plantlets (Fig.6B). However, the same interactions had significant effects on the number of roots per cutting ($p=0.0009$, Fig 6A), rooting percent ($p=0.0348$, Fig. 6C) and plantlet survival ($p=0.0357$, Fig. 6D). The number of roots per cutting (40 roots) due *S. glaucescens* (SYNA) and NAA interaction was the highest followed by SYNA x control (34 roots), the SYNA x IAA (26roots). Poorest rooting efficiency of less than 5roots per cutting was observed as due to C. sywnnertonii interacting with NAA and IAA (Fig 6C). In Fig 6C and D, the result show that the rooting efficiency as well as plantlet survival of both *S. glaucescens* and *C. sywnnertonii* did vary with type of growth regulator although the later was significantly lower than the former.

Effects of cutting type and Growth regulators interaction on root development

Figure 7 interaction between types of

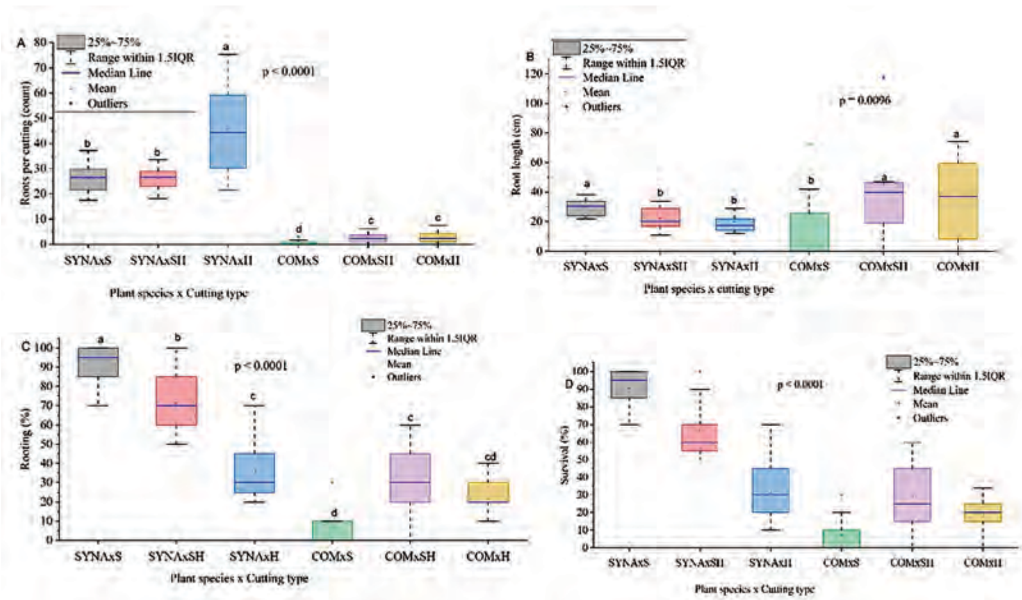

Figure 5: Influence of two-way interaction of plant species and type of cutting used for propagation on Roots per cutting (A), Root length (B), root percent (C), and plantlet survival (D). SYNA = *S. glaucescens* COM = *C. sywnnertonii*, S=Softwood, SH=semi hardwood, and H=hardwood. Means in the box plots headed by the same letters are not significantly different at α = 0.05.

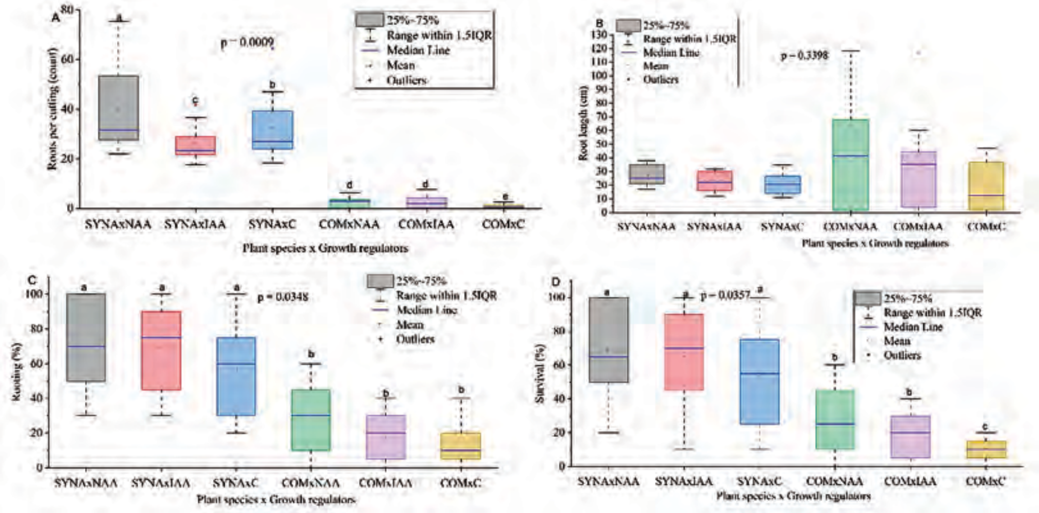

Figure 6: Influence of two-way interaction of plant species and plant growth regulators on Roots per cutting (A), Root length (B), root percent (C), and plantlet survival (D). SYNA=*S. glaucescens* COM=*C. sywnnertonii*, NAA=1-Naphthaleneacetic acid, IAA=Indole acetic acid, and C=Control (distilled water). Means in the box plots headed by the same letters are not significantly different at α = 0.05.

cutting and plant growth regulators had no substantial effects on the Average root length (p=0.9125), rooting efficiency (p=0.3323) as well as the survival of the plantlets (p=0.2093). However, the effects of the same on number of roots per plant was statistically significant (p = 0.0090). More than 30 roots per cutting was recorded due to the use of hardwood type of cutting dipped into NAA solution.

Interaction of plant species, cutting type and growth regulators on root development

A three way interaction in Figure 8 show clearly that the effects of plant growth regulators

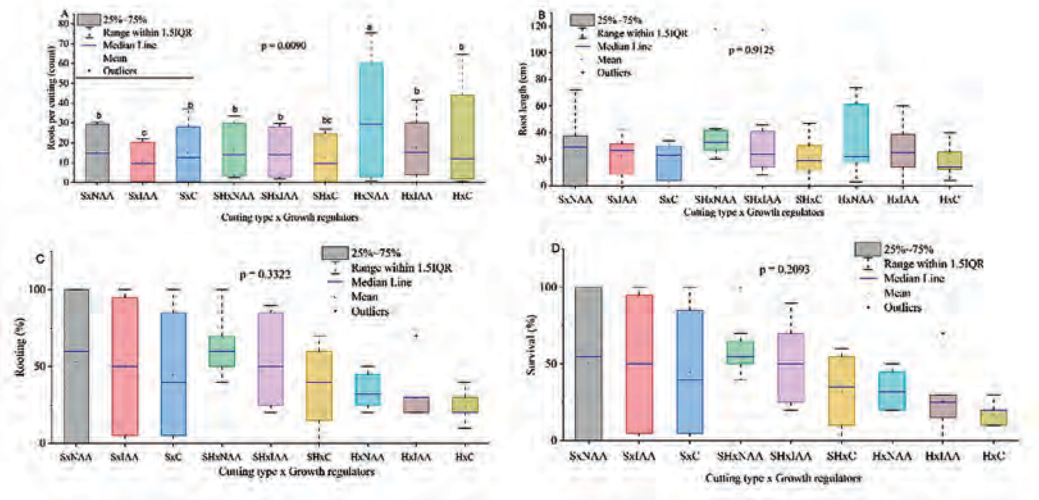

Figure 7: Influence of two-way interaction of type of cuttings and plant growth regulators on Roots per cutting (A), Root length (B), root percent (C), and plantlet survival (D). S=Softwood, SH=semi hardwood, and H=hardwood, NAA=1-Naphthaleneacetic acid, IAA = Indole acetic acid, and C=Control (distilled water). Means in the box plots headed by the same letters are not significantly different at α = 0.05.

on the number of roots per cutting (p=0.0071), rooting efficiency (p=0.0037) and the survival of the produced plantlets (p=0.0038) was significantly dependent on type of used stem cuttings as well as the type of plant. The 3-way interaction had not significant effects on the root length (p =0.8448, Fig. 8B). In Fig 8A, the plant growth regulators which were applied on all types of stem cuttings of *C. sywnnertonii* resulted into less than 5roots per cutting while between 20 and 65roots per cuttings were recorded for all three-way interactions involving *S. glaucescens*.

The use of NAA and IAA on softwood cuttings of *S. glaucescens* resulted into equally the highest rooting efficiency of 98% and 95% respectively while the use of the same plant growth regulators on semi hardwood cutting of *C. sywnnertonii* resulted into 60% and 30 % rooting with NAA and IAA applications. There was a 32% increase in rooting efficiency likened with survival of the plantlets produced from the same type of cutting of the same plant species without application of plant growth regulators, but the difference was not statistically significant. The later was not different from rooting efficiency due to *C. sywnnertonii* x Hardwood x NAA (Fig. 8C).

These results were comparable to the results on plantlet survival where by more than 98% survival was recorded in plantlets produced by softwood cuttings of *S. glaucescens* which were dipped into NAA and IAA solutions. There was a 30% increase in survival when compared with survival of the plantlets produced from the same type of cutting of the same plant species without application of plant growth regulators but this was not statistically significant. This was followed by 75% survival due to treatment of semi hardwood cutting of *S. glaucescens* with NAA and IAA. Highest survival of 50% was recorded on plantlets produced from semi hardwood cuttings of *C. sywnnertonii* which were treated with NAA followed by 30% survival plantlets produced by semi hardwood cuttings treated with IAA. Plantlets produced from semi hardwood cuttings of *C. sywnnertonii*

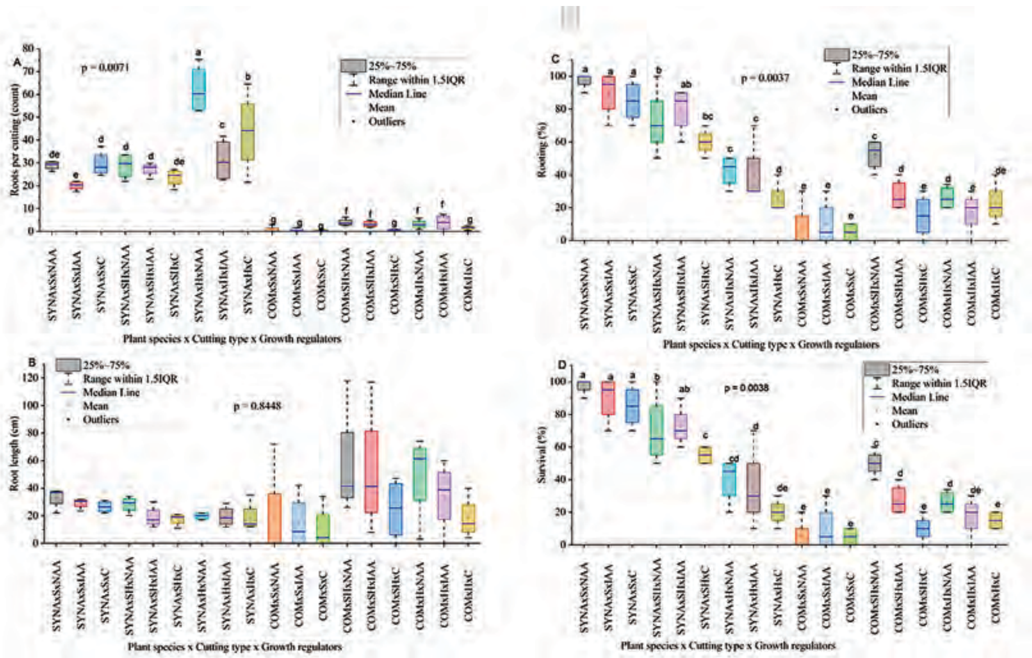

Figure 8: Influence of three-way interaction of plant species, type of cutting and type growth regulator used for propagation on Roots per cutting (A), Root length (B), root percent (C), and plantlet survival (D). SYNA = S. glaucescens COM = C. sywnnertonii, S = Softwood, SH = semi hardwood, and H = hardwood, NAA =1-Naphthaleneacetic acid, IAA = Indole acetic acid, and C = Control (distilled water). Means in the box plots headed by the same letters are not significantly different at α = 0.05

treated with both IAA and NAA gained 40% more survival than plantlets from the same type of cuttings and plant species without application of plant growth regulators.

Relationship between parameters of shoot and root development

Table 3 shows that there were positive and negative correlations between evaluated parameters of shoot and root development. Pearson correlation established significant correlations (p<0.05) between days to sprouting and number of sprouts (r=0.34), shoot length (r=0.29), number of leaves produced (r=0.40) and number of roots produced was negatively correlated (r=-0.34). Number of sprouts produced by each cutting was negatively positively correlated with the rooting efficiency (r = -0.44) and survival of the plantlets (r=-0.46). Highly significant (p<0.01) positive correlations were observed between shoot length and number of leaves per cutting (r = 0.70) as well as the root length (r = 0.53) but negatively correlated with number of roots (r = -0.49, p<0.05). Rooting of the produced shoots was correlated with survival of the plantlets by 98% (p<0.01).

to germinate, formulate seedlings or regenerate (Kwon *et al.*, 2019). This research is for the first time reporting successful vegetative propagation of *Synadenium glaucescens*. (Pax), (Family Euphobeaceae) and Commiphora swynnertonii Burttis (Family Burseraceae) that are naturally characterized of low rate of sprouting and rooting. The two plants are native species is Tanzania which are shrub or tree and grow primarily in the desert or dry shrubland biome that are among the commonly used tropical plants treating different diseases and pest control (Madege *et al.*, 2023; Matendo Rehema *et al.*, 2019).

In this research, the ability of IAA and NAA to promote sprouting and rooting of three types of cuttings; softwood, semi hardwood and hardwood was tested. A combination of plant growth regulators with different types of cuttings of each plant species increased the sprouting, rooting and survival efficiency of the plantlets although not equitably. The observed differences can be associated with the botanical nature of the two plant species where by *Synadenium glaucescens* is herbaceous while *Commiphora swynnertonii* is woody. In general, woody plants are more difficult to propagate asexually than herbaceous species, which in part is linked to the phase change from juvenility to maturation that most of them undergo (Máthé *et al.*, 2015). This argument is possibly an explanation for the observed significant difference in all sprouting and rooting parameters.

Table 3: Pearson correlations among the sprouting and rooting parameters

	DTS	S/C	SL	L/C	R/C	RL	R
Sprouts/cutting (S/C)	0.34*						
Shoot Length (SL)	0.29*	0.20					
Leaves/cutting (L/C)	0.40*	0.14	0.70**				
Roots/cutting(R/C)	-0.34*	0.04	-0.49*	-0.43			
Root Length (RL)	0.14	-0.03	0.53**	0.54	-0.14		
Rooting (R)	-0.39	-0.44*	-0.23	-0.25	0.45	0.11	
Survival (%)	-0.39	-0.46*	-0.22	-0.23	0.42	0.13	0.98**

*, ** Significant at p<0.05 and p<0.01 respectively

Discussion

Vegetative propagation is an integral process to improve the supply of the best cultivars with the highest genetic quality, which is not always recorded among sexually propagated seedlings (Erişen *et al.*, 2020; Hou *et al.*, 2020). Studies have demonstrated that vegetative propagation through stem cuttings is a popular tool for large-scale propagation of threatened plant species which have suffered from abnormal flowering and fruiting behaviours, poor abilities

Auxin is known to play an important role in stimulating rapid root formation from cuttings of plants (Omar & Khudhur, 2015; Röck-Okuyucu *et al.*, 2016; Ruchitha & Poojashree, 2021; Saif & Mohamed, 2023). In this study, the auxins-treated cuttings (IAA and NAA) showed different rooting and sprouting behaviours of both *C. sywnnertonii* and *S. glaucescens.* It can be indicated from the results of this experiment that the roots of *C. sywnnertonii* and *S. glaucescens* cuttings could be effectively formed in application of auxin. The effects of the hormone auxin group on rooting behaviours and development of different plant species have also been discussed in several studies (Saif & Mohamed, 2023; Sun *et al.,* 2023).

Auxin also has a positive effect on the number of days to sprouting rate, sprout length, leaves per cutting of both *C. sywnnertonii* and S. glaucescens. Previous reports suggest, sprouting is promoted by the cumulation of carbohydrate in cuttings which is aided by the used plant growth regulators (Hussain *et al.,* 2021; Kontoh, 2016). In this then, the application of auxin might have influenced the cuttings in some ways such that there was an increase in the root number, root length which trigger or initiate the production of root-promoting chemicals such as radiocarbon in the roots (EŞİTKEN *et al.,* 2003). Root development in cuttings create a demand for an increase in photosynthetic activity and other metabolic activities (e.g. transpiration) performed on leaves (EŞİTKEN *et al.,* 2003). Therefore, the application of auxins (IAA, NAA) might have positively affected the sprouting and leaf development of cuttings of *C. sywnnertonii* and *S. glaucescens.* The auxins helped to establish a stronger root system to help the plant to have effective in nutrient absorption. The results in this study are consistent with the role of auxin in the sprouting and leaf development of cuttings reported by other researchers (Saif & Mohamed, 2023; Sun *et al.,* 2023; Tien *et al.,* 2020; Vikas Kumar *et al.,* 2023).

Generally, it was observed that, the ability of both IAA and NAA to promote sprouting varied with the types of cutting used. For both *C. sywnnertonii* and *S. glaucescens* highest sprouting performance was attained when NAA was used to treat hardwood cuttings. These results are in line with previous studies have established best shoot response from semi hardwood cuttings compared to hardwood cuttings of Dillenia pentagyna where they concluded 500 ppm IBA was optimum for rooting (Yusnita *et al.,* 2018), IBA is an auxin growth regulators similar to IAA.

Number of sprouts and roots per cutting was significantly affected by the interaction of the three factors; plant species, the type of cuttings and type of growth regulators in line with several previous studies on different plant species (Hussain *et al.,* 2021). these studies have established that better sprouting and rooting of hardwood cuttings can be attribute to the fact that, better rooting results are obtained from cuttings taken from mature parts of the plant as compared to cuttings taken from young and tender parts (Majeed *et al.,* 2009). Furthermore, the studies have explained that in the mature parts of the plant where hardwood cuttings were taken there is high concentration of carbohydrates and carbon nitrogen ratio that help in the growth and development of sprouts as well as roots (Kontoh, 2016). Carbohydrates also enhance metabolic activities that occur around the axillary buds and at the base of the cuttings to aid cell division which brings about root initiation (Kontoh, 2016).

Results in this study also showed significant positive and negation correlations among the sprouting and rooting parameters. Days to sprouting was positively correlated with number of sprouts, shoot length and number of leaves produced in line with previous studies (Grzegorczyk-Karolak *et al.,* 2021) but negatively correlated with the number of roots per cutting. The negative correlation is possibly linked to the depletions of carbohydrates at the base of the cuttings as the carbohydrate reserve play role in the root formation. Number of sprouts produced by each cutting was negatively positively correlated with the rooting efficiency and survival of the plantlets suggesting that rooting is linked to sprouting and contradicts with previous studies which have established that root formation stimulated shoot formation to enhance photosynthesis and other metabolic activities that happens in the leaves (EŞİTKEN *et al.,* 2003; Hussain *et al.,* 2021).

In conclusion, the study has established that cutting type and plant growth regulators and their two way and three-way interactions influenced significantly the sprouting and rooting efficiency of *C. sywnnertonii* and *S. glaucescens*. The application of plant growth regulators on softwood and semi hardwood type of cuttings increased the sprouting efficiency by of 25% to 30% respectively. Since, this treatment can respond different in different environmental conditions, we recommend a similar study to be carried out under different conditions to verify the results before recommended usage in commercial cultivation.

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