

Article

Impact of Cutting Place Using Seradix 3 Powder and Planting Growth Media on Ability Growth of Some Root Characteristics for *Populus euphratica* L.

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Abstract: Poplar is the most economically important tree species in Iraq and other countries in Asia. Identification cutting places for root traits and selecting suitable planting media may be linked to the application of growth regulator (Seradix 3 powder) which could enhance the growth potential roots of the cuttings in breeding programme. However, there is limited information available on the combined effects on specific root characteristics of poplar seedlings. To this end, two types of cuttings (basal and intermediate) were treated with Seradix 3 (0.8% IBA) powder and a control (no hormone), and three planting media (sand, loam, and mixed (sand and loam 1:1)) were included in this study, which began in mid-December 2018 until the end of March 2019 in a greenhouse at the Department of Horticultural/Faculty of Agriculture/Tikrit University. The study was designed as a factorial experiment according to the randomized complete block design (RCBD) in three replications; the means were compared according to Duncan's multiple range test ($P \leq 0.05$). Rooting percentage, root length, number of first-order (lateral roots), fresh and dry weight of root systems were recorded at the end of this study. The results showed that the basal cuttings had significantly higher values compared to intermediate cuttings in all root parameters. Seradix 3 powder revealed a highly significant impact on all evaluated root parameters compared to control. Interaction of (basal cuttings (C1) + Seradix 3 (S1)) revealed gave optimal results and optimal conditions for root development. As well, the combination of (basal cutting (C1) + sand growth media (M1)) provides the most favorable conditions for robust root development. Also, the interactions of (C1 + S1 + M1) gave optimal findings compared to intermediate cuttings treated and control (untreated), these findings might help to improve and develop the growth potential of *Populus* in breeding programme.

Keywords: Poplar trees, Cutting, Seradix 3 application, Rooting

Introduction

Poplar trees (*Populus euphratica* L.) are the most economically important fast-growing hardwood for their use as ornamental trees, bioenergy, and environmental rehabilitation due to their rapid growth and adaptability [1], [2]. This species belongs to the Salicaceae family, part of the Salicales order. Including about 50 species and is widely distributed in the Northern Hemisphere, extending from the forests of North Africa to beyond the Arctic Circle in Asia and Europe. *Populus* spp. grows

naturally in Iraq along the banks of the Tigris and Euphrates rivers and their tributaries, in the valleys of mountainous regions, and on islands within the rivers. Their height rarely reaches 15 meters, and they have deciduous leaves. On young branches, the leaves are waxy and lanceolate with entire margins, while on older branches, they are ovate or triangular in shape with entire margins [3].

Vegetative propagation through stem cuttings is the primary method for large-scale production of poplar because it maintains genetic uniformity and reduces time to maturity compared to seed propagation [4]. However, the success of vegetative propagation depends on several factors, including the physiological status of the donor plant, cutting place, type of planting growth media, and application of plant growth regulators. Among these, (auxins) are the most widely used hormones to induce adventitious root formation. Indole-3-butyric acid (IBA) is preferred due to its stability and low toxicity [5], [6]. Commercial formulations such as (Seradix 3), containing 0.8% IBA, are commonly used as a powder dip to enhance rooting in hardwood cuttings. Some studies have shown that IBA concentration significantly affects poplar propagation. Cho et al. [7] reported that treatment with 10 mg L⁻¹ IBA improved growth and adaptability of poplar cuttings. Synthetic auxins can play a major role in increasing the formation, differentiation, and development of adventitious root primordia. Increased formation of lateral roots enhances the polarization of carbohydrates and compounds aiding rooting, which then interact with the auxins present at the base of the cutting, leading to increased root growth rates. Studies have proven that the synthetic hormone IBA can stimulate and promote root formation and improve rooting percentage [8].

Cutting place also plays a critical role in rooting ability. Cuttings taken from the (basal portion) of shoots generally contain more carbohydrate reserves and endogenous hormones, leading to better rooting. As confirmed by Negri et al. [9] they found that cuttings from 1-3-year-old young poplar plants rooted at 54%, while material from mature trees failed to root. Similarly, Mahmoud and Ali [10] found that basal cuttings significantly outperformed middle and terminal cuttings, and giving the highest values for the number of roots and the ratio of fresh and dry weight of the root system in black poplar (*Populus nigra* L.) seedlings.

The type of planting growth media is another key factor. Media properties such as porosity, water holding capacity, and nutrient content influence root initiation and growth. Cho et al. [7] highlighted that soil composition and physical properties severely affect root development in poplar cuttings. Substrates like peat, sand, perlite, and vermiculite are commonly used for poplar propagation.

Despite the economic importance of *Populus* spp., propagation success remains inconsistent due to variability in cutting quality and rooting environment. While many studies have investigated IBA concentration or cutting size separately, limited information is available on the combined effects of cutting place, Seradix 3 application, and planting media on specific root characteristics of poplar seedlings. Most research has focused on general rooting percentage or shoot growth, with less attention to detailed root traits such as rooting percentage, the number of first-order roots (lateral roots), root length, and dry weight of the root system. In addition, the interaction between cutting place and rooting hormone under different media conditions has not been well studied in *Populus* seedlings. This knowledge gap limits the ability of nurseries to optimize propagation protocols for maximum root system development.

The objective of this study was to determine the effect of cutting places, Seradix 3 powder, and planting growth media on the rooting ability and root development. Investigate the interaction between all studied factors to identify the optimal combination; this will help in improving and developing the growth potential of *Populus* seedlings in breeding programs.

Materials and Methods

The study was carried out at greenhouse of the Department of Horticulture/College of Agriculture/Tikrit University, during the period from mid-December 2018 until the end-March 2019. It aimed to determine the best cutting place and the best planting growth media for root developments, and to evaluate the impact of Seradix 3 powder, for root improving and enhancing the growth of *Populus euphratica* seedlings.

Experimental study was applied as a factorial experiment ($2 \times 3 \times 2$) using a Complete Randomized Block Design (CRBD) with three factors:

First factor: Cutting place (C), used (basal (C₁) and intermediate (C₂) cuttings).

Second factor: Planting growth media (M), used (Sand (M₁), Loam (M₂), and Mixed (Sand: Loam 1:1) (M₃)).

Third factor: The growth regulator (auxin application) Seradix 3 powder, which contains 0.8% of IBA (Indole Butyric Acid w/w). This was applied by dusting the base of the basal and intermediate cuttings with Seradix 3 powder to facilitate and accelerate root growth, in addition to control (without Seradix 3 powder).

Table 1. Some physical and chemical properties of the planting growth media used in this experiment.

Planting Growth Media			Physical and Chemical Properties
Mixed (Sand + Loam)	Loam	Sand	
7.11	7.09	7.01	pH
1.09	12.8	0.18	N %
0.99	2.25	0.031	P %
0.80	1.42	1.09	CEC meq/100g soil
1.38	7.01	1.11	EC dS/m
2.11	7.01	0.60	K ⁺ meq/100g soil
Sand + Loam	Loam	Sandy	Soil Texture
58	248	0.38	Clay %
755	258	97.89	Sand %
119	479	1.75	Silt %

Stem cuttings were collected from the basal and intermediate sections of mother tree branches in the early morning using pruning shears. The cuttings were 13-15 cm in length and 10-13 mm in diameter. Their bases were immersed vertically in a container of water to prevent desiccation. Ten cuttings were taken for each treatment and were planted directly into the different propagation media contained within black polyethylene bags measuring 13 × 30 cm, placed inside the plastic houses. The medium was pressed firmly around each cutting to secure it. On the first day after planting, the cuttings were lightly misted with water to prevent the rooting powder (Seradix 3) from being washed off the bases of the basal and intermediate cuttings and to maintain cutting vitality and prevent wilting. Each treatment was replicated 10 times, resulting in 12 factorial treatments and a total of 120 experimental units. At the end of the study, the following measurements for some root characteristics were taken (after 120 days):

1. Rooting of percentage (%): The percentage of rooted cuttings was calculated based on the number of rooted cuttings per treatment in each replicate using the following formula:

$$\text{Rooting Percentage} = (\text{Number of Rooted Cuttings} / \text{Total Number of Cuttings}) \times 100\%$$

2. The main of root length (cm): The length of the main root was measured from its point of connection at the soil surface to its tip using a ruler.
3. The number of first-order roots (Lateral roots).
4. Fresh weight (FW) of root system (g): FW of the root system was determined immediately after uprooting the seedling from the soil using a sensitive balance.
5. Dry weight (DW) of root system (g): DW of the root system was determined using a sensitive balance after oven-drying at 70 °C for at least 48h until a constant weight was achieved.

All data from the experiment were analyzed using the statistical analysis software application SPSS (Version 21, IBM) Armonk, NY, USA. Means were compared using Duncan's Multiple Range Test at a 5% probability level.

Results

Effect of Cutting place on root traits.

The analysis of variance (ANOVA) sources in Table 8 shown that the rooting percentage, the main of root length (RL), the number of first-order roots (lateral roots), and fresh weight (FW) and dry weight (DW) of root system differed highly significant between cutting places, between Seradix 3 treatments, and between planting growth media.

The statistical analysis regarding the influence of cutting places on root development, as detailed in Table 2, reveals statistically significant variances between basal (C₁) and intermediate (C₂) cuttings across all evaluated root morphological parameters. According to Duncan's test, the selection of the cutting place profoundly impacted rooting percentages, the main of root length (RL), the number of first-order roots (lateral root), and overall biomass accumulation. C₁ recorded the highest value for these traits (68.78%, 16.28 cm, 13.96 lateral roots, 0.788 g, and 0.341 g) respectively. The utilization of basal cuttings led to a significant enhancement in root development compared to intermediate cuttings, representing percentage increases of 4.67% in rooting, 7.98% in root length, 92.76% in lateral root count, 27.41% in fresh weight, and 19.65% in dry weight. Conversely, intermediate cuttings (C₂) recorded the lowest average growth metrics across all evaluated root traits (64.11%, 14.98 cm, 10.01 secondary roots, 0.572 g, and 0.274 g) respectively.

Table 2. Effect Cutting places (basal (C₁) and intermediate (C₂) cuttings) on some root traits. (First-order roots (lateral roots), RL= root length, FW = Fresh Weight, DW= Dry Weight)

Traits Cutting place	Percentage of rooting (%)	The main of RL (cm)	No. of first-order roots	FW of root system (g)	DW of root system (g)
C ₁	68.78 ^a	16.28 ^a	13.96 ^a	0.788 ^a	0.341 ^a
C ₂	64.11 ^b	14.98 ^b	10.01 ^b	0.572 ^b	0.274 ^b

Effect of Seradix 3 application on root traits.

The application of Seradix3 powder (S₁) demonstrated a highly significant impact on all evaluated root parameters compared to the untreated control (S₀), as determined by Duncan's test in table (3). The experimental results indicate that treated cuttings with Seradix 3 powder achieved a superior rooting percentage of 81.83%, representing a significant increase over the 51.06% observed in the control group. In terms of morphological development, Seradix3 treatment fostered enhanced root architecture, yielding a mean root length (RL) of 17.04 cm and an average of 12.87 first-order (lateral) roots per cutting. In contrast, the control treatment (without Seradix 3 powder) recorded lower averages for these traits, with a mean root length of 14.22 cm and 11.09 lateral roots. Biomass accumulation was also significantly higher in the treated group, with the fresh weight (FW) and dry weight (DW) of the root systems reaching 0.733 g and 0.332 g, respectively. Comparatively, the untreated cuttings recorded a fresh weight of 0.628 g and a dry weight of 0.283 g. Proportionally, cuttings treated with Seradix 3 powder led to significant relative increases across all studied root traits, specifically (30.77%) for rooting percentage, (16.55%) for root length, (13.83%) for lateral root proliferation, (14.32%) for fresh weight; and (14.76%) for dry weight.

Table 3. Effect of Seradix 3 (S₁) and Control without Seradix3 (S₀) treatments on some root traits. (First-order roots (lateral roots), RL= root length, FW = Fresh Weight, DW= dry weight)

Traits Seradix3 Treatments	Percentage of rooting (%)	The main of RL (cm)	No. of first-order roots	FW of Root system (g)	DW of root system (g)
S ₀	81.83 ^a	17.04 ^a	12.87 ^a	0.733 ^a	0.332 ^a
S ₁	51.06 ^b	14.22 ^b	11.09 ^b	0.628 ^b	0.283 ^b

Effect of planting growth media on root traits.

The experimental data presented in Table (4) indicates that the selection of planting growth media exerts a statistically significant influence on all evaluated root parameters. Sand media emerged as the most effective growth medium for the majority of studied traits. It recorded the highest values for rooting percentage (71.33%), root length (17.25 cm), and first-order (lateral) roots (12.82). While, loam media (M₂) was significantly more effective for promoting root system fresh weight (FW), recording the peak average of (0.711 g). However, loam media also recorded the lowest values for rooting percentage (62.00%) and the number of first-order (lateral) roots (11.52). The mixed medium substrate (sand + loam) generally underperformed relative to the single-component media, yielding the lowest mean values for root length (14.42 cm), fresh weight (0.663 g), and dry weight (0.287 g). Meanwhile, values the dry weight (DW) of root system in sand (0.321 g) did not differ significantly in effect from those grown in loam (0.315 g), also the number of first-order (lateral) roots in loam (11.52) did not differ significantly in effect from those grown in mixed (Sand + loam) (11.61).

Table 4. Effect of planting growth media (sand (M₁), loam (M₂), mix (sand + loam) (M₃) on some root traits. (First-order roots (lateral roots), RL= root length, FW = Fresh Weight, DW= dry weight)

Traits Planting Growth Media	Percentage of rooting (%)	The main of RL (cm)	No. of first-order roots	FW of Root system (g)	DW of root system (g)
M ₁	71.33 ^a	17.25 ^a	12.82 ^a	0.667 ^b	0.321 ^a
M ₂	62.00 ^c	15.23 ^c	11.52 ^b	0.711 ^a	0.315 ^a
M ₃	66.00 ^b	14.42 ^b	11.61 ^b	0.663 ^b	0.287 ^{ab}

Means with the same letter are not significantly different according to Duncan's test at the 5% probability level.

The effect of interactions among studied factors on root traits.

Percentage of rooting, the main of first-order roots (lateral roots), and DW of root system in Table (8) showed a highly significant interaction between Seradix3 treatments and cutting places and between cutting places and planting growth media. However, there were no significant different for the first-order (lateral) roots and FW of root system. Interaction among all studied factors revealed there were a highly significant interaction for all studied root traits, expect for the percentage of rooting, and DW of root system.

The interaction between cutting place and Seradix 3 treatment impacted significantly on all evaluated root parameters. Analysis of the data presented in Table (5) reveals that basal cuttings treated with Seradix3 (C₁S₁) were consistently superior, gaving the highest mean values for rooting percentage (85.89%), root length (17.57 cm), number of first-order (lateral) roots (14.73), and root system biomass, with fresh and dry weights of 0.841 g and 0.373 g, respectively. In contrast, the lowest performance across these traits was observed in the interaction between intermediate cuttings and the control (non-hormone) treatment (C₂S₀), which recorded a rooting percentage of 50.44%, a root length of 13.45 cm, and only 9.01 lateral roots. The C₁S₁ treatment interaction represented a substantial statistical increase over the C₂S₀ control, with improvements equivalent to 41.23% in rooting percentage and 31.09% in dry

weight. However, intermediate cuttings treated with Seradix 3 (C₂S₁) followed as the second most effective interaction for rooting percentage (77.78%) and root length (16.51 cm). Basal cuttings without Seradix3 (C₁S₀) outperformed them in terms of the number of lateral roots (13.18) and fresh weight (0.735 g).

Table 5. Effect of Cutting places treated with Seradix 3 interaction on some root traits. (First-order roots (lateral roots), RL= root length, FW = Fresh Weight, DW= dry weight)

Traits Treatments	Percentage of rooting (%)	The main of RL (cm)	No. of first-order roots	FW of root system (g)	DW of root system (g)
C ₁ S ₀	51.67 ^c	14.99 ^c	13.18 ^b	0.735 ^b	0.310 ^{ab}
C ₁ S ₁	85.89 ^a	17.57 ^a	14.73 ^a	0.841 ^a	0.373 ^a
C ₂ S ₀	50.44 ^d	13.45 ^d	9.01 ^d	0.521 ^c	0.257 ^c
C ₂ S ₁	77.78 ^b	16.51 ^b	11.01 ^c	0.624 ^b	0.291 ^b

Means with the same letter are not significantly different according to Duncan's test at the 5% probability level.

The analysis of the interaction between cutting place (C) and planting media (M) reveals a significant impact on all evaluated root parameters, as detailed in Table (6). According to Duncan's test at a 5% probability level, the interaction between basal cuttings and sand growth media (C₁M₁) showed a marked superiority over all other treatments. This specific combination yielded the highest mean values for rooting percentage (77.17%), root length (18.06 cm), number of first-order (lateral) roots (15.49), fresh weight (0.817 g), and dry weight of the root systems (0.393 g). Compared to the interactions yielding the lowest values, the C₁M₁ treatment resulted in significant percentage increases across all traits, most notably a 41.23% improvement in rooting percentage and a 31.09% increase in dry weight. Specifically, the lowest performance for rooting percentage (62.00%) was observed in both basal and intermediate cuttings when planted with loam growth medium (C₁M₂ and C₂M₂). The minimum values for root length (13.57 cm) and lateral root numbers (9.32) were recorded in the interaction between intermediate cuttings and mixed growth media (C₂M₃). Furthermore, the interaction between intermediate cuttings and sand (C₂M₁) produced the lowest biomass, with a fresh weight of 0.517 g and a dry weight of 0.250 g. Regarding to secondary performance rankings, the basal cuttings in mixed growth medium (C₁M₃) recorded second for rooting percentage (67.17%), lateral roots (13.90), and fresh weight (0.739 g). For dry weight, basal cuttings in loam (C₁M₂) followed the primary interaction with 0.324 g, while intermediate cuttings in sand (C₂M₁) recorded the second-highest root length at 16.43 cm.

Table 6. Effect of Cutting places and Planting Growth Media interaction on some root traits. (First-order roots (lateral roots), RL= root length, FW = Fresh Weight, DW= dry weight)

Traits Treatments	Percentage of rooting (%)	The main of RL (cm)	No. of first-order roots	FW of root system (g)	DW of root system (g)
C ₁ M ₁	77.17 ^a	18.06 ^a	15.49 ^a	0.817 ^a	0.393 ^a
C ₁ M ₂	62.00 ^d	15.51 ^c	12.47 ^c	0.810 ^a	0.324 ^b
C ₁ M ₃	67.17 ^b	15.28 ^c	13.90 ^b	0.739 ^b	0.307 ^c
C ₂ M ₁	65.50 ^c	16.43 ^b	10.14 ^d	0.517 ^d	0.250 ^d
C ₂ M ₂	62.00 ^d	14.96 ^{cd}	10.57 ^d	0.612 ^c	0.306 ^c
C ₂ M ₃	64.83 ^c	13.57 ^d	9.32 ^d	0.588 ^d	0.267 ^d

Means with the same letter are not significantly different according to Duncan's test at the 5% probability level.

The statistical evaluation of the tripartite interaction between cutting places, Seradix3 application, and planting growth media reveals a profound influence on the development of all root traits. Analysis of the data in Table (7) shows that the optimal configuration for root enhancement was

achieved through the interaction of basal cuttings treated with Seradix3 and cultivated in a sand medium (C₁S₁M₁). This specific treatment combination yielded peak mean values across all phenotypic traits: a rooting percentage of 93.67%, a mean root length of 21.26 cm, 16.33 first-order lateral roots, a fresh weight of 0.902 g, and a dry weight of 0.424 g. The efficacy of the C₁S₁M₁ interaction was further underscored by its significant statistical deviation from treatments exhibiting the lowest growth metrics. Specifically, compared to the basal untreated loam interaction (C₁S₀M₂), which recorded the lowest rooting percentage at 45.00%, the C₁S₁M₁ treatment represented a substantial 51.95% improvement. Furthermore, the C₁S₁M₁ combination outperformed the intermediate untreated mixed media (C₂S₀M₃) and intermediate untreated sand (C₂S₀M₁) interactions, which yielded the minimum values for root length (12.57 cm), lateral root number (7.82), and dry weight (0.231 g), respectively. These superior results for C₁S₁M₁ represent percentage increases ranging from approximately 41% to 52% across the evaluated root traits. Regarding secondary performance tiers, the basal treated loam interaction (C₁S₁M₂) emerged as a significant performer, particularly in rooting percentage (79.00%) and fresh weight (0.845 g), where it exhibited no statistically significant difference from the intermediate treated sand interaction (C₂S₁M₁). Additionally, basal treated mixed media (C₁S₁M₃) demonstrated robust development in the number of first-order roots (14.57), while the C₂S₁M₁ interaction provided the second-highest mean root length at 18.40 cm.

Table 7. Effect of Cutting places (C), Seradix 3 treatment (S) and Planting Growth Media (M) interaction on some root traits. (First-order roots (lateral roots), RL= root length, FW = Fresh Weight, DW= dry weight)

Treatments	Percentage of rooting (%)	The main of RL (cm)	No. of first-order roots	FW of roots (g)	DW of roots (g)
C ₁ S ₀ M ₁	60.67 ^e	14.87 ^d	14.67 ^b	0.731 ^e	0.362 ^{bc}
C ₁ S ₀ M ₂	45.00 ^h	14.51 ^d	11.63 ^d	0.700 ^e	0.287 ^d
C ₁ S ₀ M ₃	49.33 ^g	15.60 ^c	13.24 ^c	0.755 ^e	0.280 ^d
C ₁ S ₁ M ₁	93.67 ^a	21.26 ^a	16.33 ^a	0.902 ^a	0.424 ^a
C ₁ S ₁ M ₂	79.00 ^c	16.50 ^c	13.30 ^c	0.845 ^b	0.361 ^b
C ₁ S ₁ M ₃	85.00 ^b	14.96 ^d	14.57 ^b	0.777 ^c	0.333 ^{bc}
C ₂ S ₀ M ₁	52.00 ^f	14.46 ^d	9.31 ^{fg}	0.487 ^e	0.231 ^d
C ₂ S ₀ M ₂	51.00 ^f	13.33 ^e	9.90 ^f	0.545 ^c	0.289 ^d
C ₂ S ₀ M ₃	48.33 ^{gh}	12.57 ^f	7.82 ^{fg}	0.530 ^c	0.250 ^d
C ₂ S ₁ M ₁	79.00 ^c	18.40 ^b	10.98 ^d	0.546 ^c	0.268 ^d
C ₂ S ₁ M ₂	73.00 ^d	16.58 ^c	11.24 ^{de}	0.679 ^d	0.323 ^e
C ₂ S ₁ M ₃	81.33 ^{bc}	14.56 ^d	10.82 ^e	0.646 ^d	0.284 ^d

Means with the same letter are not significantly different according to Duncan's test at the 5% probability level.

Table 8. Summary ANOVA results for the effects of block, Seradix3 treatment (S), Cutting place (C) and Planting Growth Media (M) and interaction effects on some root traits of *Populus euphratica*. Root data were recorded at the end of this study. NS (Not significant), * < 0.05, ** < 0.01 and *** < 0.001, respectively, n=12 for each sapling.

Source of variation (degree of freedom)	Block (3)	Cutting (C) (2)	Seradix (S) (2)	Media(M) (3)	S × C (1)	C × M (2)	S × M (2)	S × C × M (2)
1. Percentage of cutting roots	0.101 ^{ns}	9.392 ^{**}	408.53 ^{***}	12.608 ^{**}	5.117 [*]	5.479 [*]	1.507 ^{ns}	0.804 ^{ns}
2. The main of root length	5.484 ^{ns}	11419.32 ^{***}	53893.79 ^{***}	19120.23 ^{***}	388.400 ^{***}	11433.38 ^{***}	948.438 ^{***}	3903.455 ^{***}
3. No. of first-order roots (Lateral roots)	0.341 ^{ns}	511.23 ^{***}	103.98 ^{***}	23.14 ^{***}	1.672 ^{ns}	1.305 ^{ns}	36.13 ^{***}	3.117 ^{**}
4. Wet weight of root system	0.072 ^{ns}	1169.68 ^{***}	273.63 ^{***}	23.53 ^{***}	0.084 ^{ns}	0.780 ^{ns}	48.58 ^{***}	19.07 ^{***}
5. Dry weight of root system	1.934 ^{ns}	907.48 ^{***}	479.99 ^{***}	89.687 ^{***}	40.621 ^{***}	1.905 ^{ns}	301.25 ^{***}	2.146 ^{ns}

Discussion

Root morphological traits influenced significantly between basal and intermediate cuttings in response to Seradix3 application and planting growth media used in this study. These variations may affect in root ability depending on the cutting position used. The effects of cutting places with Seradix 3 applications and planting growth media are discussed below, focusing primarily on root aspects in this study.

The research indicate that the utilization of basal cuttings had significantly higher enhancement in rooting percentage, number of first-order (lateral roots), root length, fresh and dry weight of root systems compared to intermediate cuttings, as shown in table (2). The reason might be to higher carbohydrate reserves and greater accumulation of endogenous auxins in the basal cuttings. Auxin facilitates the metabolic mobilization of starch into sugars by increasing the activity of carbohydrate metabolism enzymes, which provides the energy necessary for rapid cell division and elongation [11], which help to improve the growth of root system.

The difference in the content of carbohydrates (nutrients) at the bases of the cuttings, which may play an important role in root growth, especially in the early stages of the root formation process for cuttings [12]; and thus an increase in the number of first-order roots (lateral roots) causes an increase in the fresh and dry weight of root system. This finding is supported by Byeon and Lee [13] who explained that high-rooting poplar clones showed upregulation of genes related to auxin signaling, cell wall differentiation, and flavonoid biosynthesis 2 weeks after cutting. These physiological advantages are more pronounced in basal cuttings.

Also, these results in this study agree with other established research. Desrochers and Thomas [14] found that basal cuttings consistently outperformed of poplar trees gave the highest averages for rooting percentage and root length when compared to middle and terminal cuttings. Similarly, Sivaji et al. [15] showed that basal cuttings consistently outperformed middle and terminal sections in rooting percentage and root length for *Ficus carica*. Saladdin [16] found that basal cuttings gave a significant increase in the effect on the dry weight of the root system compared to middle and terminal cuttings, during the propagation of *Callistemon viminalis* L. seedlings.

The application of Seradix3 powder (0.8% IBA) recorded substantially greater growth averages than the (non-hormonal) control. This confirms the role of exogenous auxin in overcoming apical dominance and stimulating root primordia formation, which is consistent with the commercial practice of using 0.3-0.8% IBA for hardwoods. Due to the high concentration of IBA, it might lead to inhibited growth. This is emphasized by Cho et al. [7], who explained that excessive IBA (100 mg L⁻¹) could inhibit growth, indicating an optimal concentration range exists. As well, Darouez et al. [17] revealed that synthetic auxin prodrugs had stronger root including effects than standard IBA in *Populus × canadensis*, confirming the central role of auxin in root formation. Otherwise, these findings underscore

the efficacy of Seradix3 in promoting robust root system development and overall cutting success. These might be an exogenous auxins serve as a critical catalyst when endogenous levels are insufficient, promoting the movement of nutrients and sugars toward the cutting base through nutrient polarization, causing them to respond well when treated with the hormone [18], and thus treating cuttings with the hormone leads to an increase in rooting percentage [19], and number of roots in a better way at the cutting base [20], comparing to untreated cuttings.

The selection of planting growth media is a decisive factor in rooting success, with sand-based media providing the most favorable conditions for robust development. The superior performance of sand is largely due to optimal aeration, which ensures that the active meristematic cells at the root tips have access to the oxygen required for metabolic processes. In contrast, loam and mixed media often suffer from poor aeration, which may inhibit root initiation. The reason for the low rooting percentage in basal and intermediate cuttings untreated with hormone and planted in the loam and mixed growth media may be attributed to poor aeration, which may reduce the need of the active meristematic cells at the root tips for oxygen [21]. Additionally, environmental variables such as soil moisture [22] and temperature [23] play vital roles in the effectiveness of the rooting process.

Interactions among studied factors in this research affected root parameters across all cuttings. Values for rooting percentage, root length, number of first-order roots, FW and DW of root system were higher for basal cuttings growing in sand planting media than intermediate cuttings, these differences are statistically significant, highlighting that the combination of basal cutting placement and Seradix3 application. As well, the combination of basal cutting placement and a sand-based medium provides the most favorable conditions for robust root system development. This emphasized by Wang et al. [24] reported that poplar species have performed root initials that require wounding and auxin to develop into adventitious roots; thus the combination of a physiologically competent cutting 'basal' and optimal auxin concentration (0.8% IBA) maximizes this response. Also, Cho et al. [7] demonstrated that soil composition and cutting quality severely affect root growth; thus combining good cutting selection with IBA treatment and proper substrate is essential. The results align with current nursery protocols that include basal cuttings and 0.8% IBA powder dips. While, the lower response in intermediate cuttings, even with Seradix 3, might be due to lower carbohydrate concentration and a higher cytokinin/auxin ratio, which inhibits root initiation as demonstrated by Wei et al. [25].

The data in this study confirms a significant synergy between the use of basal cuttings, the application of Seradix3, and a sand-based substrate. According to Duncan's test at a 5% probability level, this specific combination creates the optimal environment for maximal root system proliferation and overall propagation success. These results agree with [8], who found a significant increase in the percentage of rooting of *Pelargonium zonale* cuttings planted in the sand growth medium compared to cuttings planted in other growth medium. Cuttings may adjust their morphology root traits in response to competition for soil resources such as the availability of water and nutrients.

Conclusion

1. The experimental data identifies that the basal cuttings as the optimal position for propagation, Cutting place highly significantly impact on rooting ability and root traits.
2. Seradix 3 (0.8% IBA) powder treatments highly significantly enhanced all root traits.
3. Sand media (M1) gave optimal results for maximizing rooting success and structural development, while loam media (M2) is most conducive to increasing fresh biomass.
4. The interactions of (basal cuttings (C1) + Seradix 3 (0.8% IBA) powder (S1)) and the interactions of (basal cuttings (C1) + Seradix 3 (0.8% IBA) powder (S1) + sand growth media (M1)) gave optimal findings for all studied traits compared to intermediate cuttings treated and a control (untreated), and recommended for vegetative propagation of *Populus* seedlings.

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