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Rating the conservation potential of *Tecomella undulata* using macropropagation techniques for sustainable restoration

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Abstract

Tecomella undulata (Bignoniaceae) is a valuable multipurpose agroforestry tree species prized for its high-quality timber, medicinal properties, soil-binding capacity, and effectiveness as a windbreak. However, overexploitation, habitat degradation, and poor natural regeneration have led to a decline in its natural populations, highlighting the need for efficient vegetative propagation techniques to support its conservation and large-scale cultivation. This study evaluated the macropropagation potential of stem cuttings treated with Indole-3-acetic acid (IAA) and Indole-3-butyric acid (IBA) at concentrations of 4000 and 6000 ppm, applied individually and in combination. Seven treatments, including an untreated control, were evaluated under field conditions at the University of Agriculture Faisalabad. Stem cuttings treated with IAA at 6000 ppm exhibited the highest sprouting percentage (62.5%) and the earliest leaf emergence, indicating its effectiveness in promoting bud break and shoot development. In contrast, the combined application of IAA and IBA resulted in the lowest sprouting percentage (0.4%). The IAA 6000 ppm treatment also recorded the highest survival rate (8.3%) and the lowest mortality rate (16.7%). However, none of the treatments induced root formation. These findings suggest that IAA at 6000 ppm is the most effective treatment for enhancing sprouting and survival in T. undulata stem cuttings. Nevertheless, further research is required to optimize rooting protocols and establish an efficient clonal propagation system for the conservation and sustainable utilization of this threatened species.

1 Introduction

Tecomella undulata is native to Pakistan, India, Arabia, and Afghanistan. In Pakistan, it occurs in almost all provinces of the state, i.e., Punjab, Sindh, Baluchistan and NWFP. It is also planted along the roads and canal in a linear formation. In India, it occurs in Maharashtra, Haryana, Punjab, Gujarat, and Rajasthan. Due to its mycorrhizal and symbiotic nature, it could be used for research purposes, bio fertilizer and for afforestation in the arid areas. This plant species has unique properties such as fire resistance, acts as a phytoremediator and is susceptible to drought stress (Shankar Narayan and Nanda, 1963; Srivastava *et al.,* 2004 and Mathur *et al.,* 2010). *T. undulata* is a naturally growing agroforestry tree in the area of Thar Desert (Rajasthan). It is a hardy tree plant and can grow in all ecological zones (Singh *et al*., 2004).

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T. undulata should be kept under keen observation to promote its conservation efforts (Sharma 1986 and Khan 1997). Current value and status of local plants in Karachi, including *T. undulata* found to be a severely threatened timber species (Hussain *et al.* 2010; Khan *et al*., 2023). Macro-propagation of *T. undulata* ecotype in India, which indicated that the rooting response of *T. undulata* stem cuttings was influenced by several factors such as donor trees health, physiological status of cuttings and the external environmental conditions (Kumar *et al.* 2008). *Tecomella undulata* litter shows comparatively favorable C: N and N-dynamics and enhances soil faunal activity during decomposition, indicating a supportive environment for microbial communities (Tripathi, 2011; Verma *et al*., 2021; Yasin *et al*., 2024).

A remarkable success rate of root formation in Lahoora cuttings by the application of PGRs. The research was carried out in late autumn and late winter. In the first phase of the experiment, 0.3% concentration of NAA over semi-hardwood stem cuttings resulted in 82.9% rooting rate and over hardwood stem cuttings same concentration of NAA resulted in 89.4% rooting, whereas 4% concentration of IBA over semi-hardwood stem cuttings resulted in 80.6% rooting success and same concentration of IBA over hardwood stem cuttings resulted in 81.7% rooting (Karami and Salehi 2010; Afzal *et al*., 2020).

Macro-propagation was applied on *T. undulata* to study the effect of indole-3-butyric acid (IBA), along with the association of stem cuttings position with different genotypic expressions, varying thickness of stem cuttings, different seasons, trees with different management, coating with wax, and different types of containers. In that experiment, indole-3-butyric acid (IBA) was not effective for rooting. January to March (late winter) was found to be the most suitable time for root development, which was 15%. From July to December, no root initiation was observed. Discussing the genotypes, 4 trees of different genotypes (genotype no 9, 12, 17 and 21) were selected. 99% was the highest sprouting percentage, along with 48.1% embryonic root development percentage and 10.4% rooting response was noted in genotype no. 9. Cuttings which were collected from the middle crown canopy were highly rooted (33.3%). Stem cuttings of genotype no. 9 observed buds for flowers and later on mature flowers in a mist polyhouse. This bud initiation and flower production was not found in any other genotype (Tyagi *et al.* 2011).

Different sexual and asexual reproduction methods were adopted on *T. undulata* to study the rooting response. Rooting percentage with IBA at a concentration of 6000 ppm was 35.72%. IBA at a concentration of 4000 ppm showed negative results. Survival rate through different macro-propagation methods was as follows: rooting success was higher in root suckers of *T. undulata*, which was 27.78%. During the spring seasons emergence of coppice shoots was admirable on stumps that were about 1 year of age (Kaur *et al.* 2019; Rahman *et al*., 2025).

This study represents one of the earliest experimental approaches in Pakistan aimed at conserving *Tecomella undulata*, a desert tree species of high ecological and economic importance. Unlike previous studies that largely documented its poor natural regeneration, this research explored macropropagation using different auxin treatments. While rooting was not achieved, significant differences in sprouting and survival responses were observed, especially with IAA at higher concentrations. These results not only highlight the limitations of current methods but also provide a critical starting point for developing improved propagation strategies and ensuring the long-term conservation of this endangered species.

2. Materials and Methods

Research area

The research was conducted in the Post Graduate Research Area, Department of Forestry and Range Management, University of Agriculture, Faisalabad.

Cutting collection and preparation

Cuttings of *T. undulata* were collected from Lal Suhanra National Park, Bahawalpur, Pakistan and shifted to the research area with intense care. Cuttings of thumb thickness (mature to semi-mature) of 9-12 inches with 3-4 eyes were prepared and then treated by PGRs (IAA & IBA).

Bed preparation for placing cuttings

In the asexual propagation technique, cuttings were planted in polythene bags. 9-12 inches in length of cuttings were maintained. The bags were filled with sandy loam soil with FYM. The bags were placed under partial shady area. And after that, it was covered with polythene by making the tunnel.

Preparation of Solutions

Preparation of IAA Solutions

Indole-3-Acetic Acid is insoluble in water. If solvents have an alkaline pH, then IAA could be soluble. It is soluble in 1N NaOH and some organic solvents like ethanol, DMSO and DMF. A stock solution of IAA-6000 ppm was prepared by dissolving 6 grams of Light Tan Crystalline Powder of IAA in 5% of Ethanol. Sterilize the solution using a magnetic stirrer. Distilled water was added to make it a 500 ml solution. A clear reddish-brown colored solution was obtained. The same procedure was repeated, but the amount of IAA was decreased to 4 g and a solution of IAA-4000 ppm was obtained.

Preparation of IBA Solutions

Indole-3-Butyric Acid could be soluble in distilled water, but preferably, an IBA-6000 ppm solution was prepared by adding 6 grams of white to pale yellow powder of IBA to 5 ml of ethanol. Sterilize the solution using a magnetic stirrer. Distilled water was added to make it 500 ml solution. A clear, slightly yellow colored solution was obtained. The same procedure was repeated, but the amount of IBA was decreased to 4 g and a solution of IBA-4000 ppm was obtained.

Experimental Design

The experiment consisted of 7 treatments.

T1 : IAA-4000 ppm
T2 : IBA-4000 ppm
T3 : IAA-6000 ppm
T4 : IBA-6000 ppm
T5 : IAA-4000 ppm + IBA-4000 ppm
T6 : IAA-6000 ppm + IBA-6000 ppm
T7 : Control

Every treatment was replicated thrice and each replication had 4 plants, so the total number of cuttings was 84. Two phytohormones (IAA and IBA) were used in two concentrations and their combinations as discussed earlier (Afzal *et al*., 2005).

Plantation of cuttings

After the preparation of solutions, the basal area of prepared cuttings was dipped in solutions for a period of 60 seconds. Cuttings were planted in polythene tubes, filled with sandy soil.

Parameters recorded

Leaf initiation and number of leaves

On daily based observation, all the cuttings were observed and date wise first leaf initiated was recorded in all cuttings of different treatments. The first leaf was initiated after the 4th day of cutting the plantations. Number of leaves on first observation after 7 days of plantation of cuttings. Data were collected and each leaf on the cutting was counted and the mean of them was calculated.

Number of roots in cuttings

Root initiation was the major parameter. Unfortunately, no root was developed in the cuttings treated with different concentrations of PGRs.

Sprouting %age

Sprouting at regular intervals was observed. All the sprouted cuttings were counted and the percentage of sprouting was then calculated through the following formula. (Satisha *et al.,* 2008; Somkuwar *et al.,* 2011)

$$\text{Sprouting \%age} = \frac{\text{No. of cuttings sprouted}}{\text{Total no. of cuttings planted}} \times 100$$

Mortality %age:

All the dead cuttings were counted at regular intervals. Mortality percentage was calculated by the following formula.

$$\text{Mortality \%age} = \frac{\text{No. of cuttings dead}}{\text{Total no. of cuttings planted}} \times 100$$

Survival %age:

The number of cuttings that survived at the end of the study was counted and the survival percentage was calculated by the following formula.

$$\text{Survival \%age} = \frac{\text{No. of cuttings sprouted}}{\text{Total no. of cuttings planted}} \times 100$$

Statistical analysis

The experiment was designed in a Complete Randomized Design (CRD) and the data were analyzed by ANOVA and LSD.

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3. Results

General observations:

The experiment was conducted in November to develop a conservation strategy for *Tecomella undulata* using macropropagation. Thumb-thick, mature to semi-mature stem cuttings were treated with different concentrations of IAA, IBA and their combinations, then placed under a polythene-covered mini-greenhouse to minimize stress and maintain temperature. Sprouting began 5 days after planting and continued up to 21 days, with marked variation among treatments.

Cuttings treated with IAA 6000 ppm exhibited the highest and fastest sprouting, followed by IBA 6000 ppm and IAA 4000 ppm, whereas combined IAA+IBA treatments and controls showed delayed and poor sprouting. Leaf production was also greatest under IAA 6000 ppm, while controls produced the fewest and most desiccated leaves. Mortality was lowest in cuttings treated with IAA 4000 ppm, while untreated cuttings had the highest mortality. Maximum survival was recorded under IAA 6000 ppm; the lowest under combined IAA 6000 ppm + IBA 6000 ppm.

By 21–28 days after planting, most cuttings had wilted and dried. Uprooting revealed no adventitious root formation in any treatment, suggesting that the lack of rooting was the main cause of poor survival of sprouted cuttings.

Sprouting percentage (%)

Daily observations showed significant differences in sprouting percentage among treatments. Sprouting percentage varied significantly across treatments (Table 1). The order of response was T3 > T4 > T1 > T2 = T6 > T5 > T7. The highest sprouting (63.3 %) occurred in T3 (IAA 6000 ppm), followed by T4 (58.3 %) and T1 (50.0 %). T2 and T6 both produced 41.7 %, while T5 gave 33.3 %. The control (T7) had the lowest sprouting (25.0 %) (Fig. 1). These findings agree with previous studies reporting high sprouting under auxin treatments: 99 % sprouting was achieved in T. undulata with IBA (Tyagi et al. 2011), and similar responses were observed in Psidium guajava **(**Kareem et al. 2016). The variation in our results may reflect differences in planting time, site conditions, cutting type, or auxin formulation. Overall, IAA and IBA effectively enhanced bud initiation and leaf emergence in T. undulata cuttings.

Table 1: Analysis of variance for sprouting percentage

Source	DF	SS	MS	F	P
Treatment	6	16741.1	2790.18	4.24	0.0010**
Error	77	50729.2	658.82		
Total	83	67470.2			

Grand Mean =32.738 ; CV = 78.40

** = *significant* at $P \leq 0.01$ and NS = non-significant at $P \leq 0.05$, respectively.

Leaf initiation:

Daily monitoring recorded the date of first and second leaf emergence in all cuttings. The first leaf appeared 4 days after planting across treatments. Statistical analysis showed non-significant differences among treatments for both first and second leaf initiation, Table 2(a & b). The trend for first-leaf emergence was T3 > T1 ≥ T2 ≥ T5 > T4 > T6 > T7, while for second-leaf emergence it was T3 > T2 > T6 > T1 > T4 > T5 > T7. T3 (IAA 6000 ppm) had the highest mean values for both parameters, whereas T7 (control) recorded the lowest (Fig. 2a, b). Comparable parameters have not been reported previously for *T. undulata* cuttings.

Table 2 (a): Analysis of variance for date of 1st leaf initiation

Source	DF	SS	MS	F	P
Treatment	6	73.619	12.6032	0.30	0.9051
Error	77	4137.667	40.9048		
Total	83	3221.286			

Grand Mean 14.357 CV 18.30

** = *significant* at $P \leq 0.01$ and NS = non-significant at $P \leq 0.05$, respectively.

Table 2 (b): Analysis of variance for date of 2nd leaf initiation

Source	DF	SS	MS	F	P
Treatment	6	32.905	5.48413	1.46	0.2022
Error	77	288.667	3.74892		
Total	83	321.571			

Grand Mean =23.929 ; CV = 8.09

** = *significant* at $P \leq 0.01$ and NS = non-significant at $P \leq 0.05$, respectively.

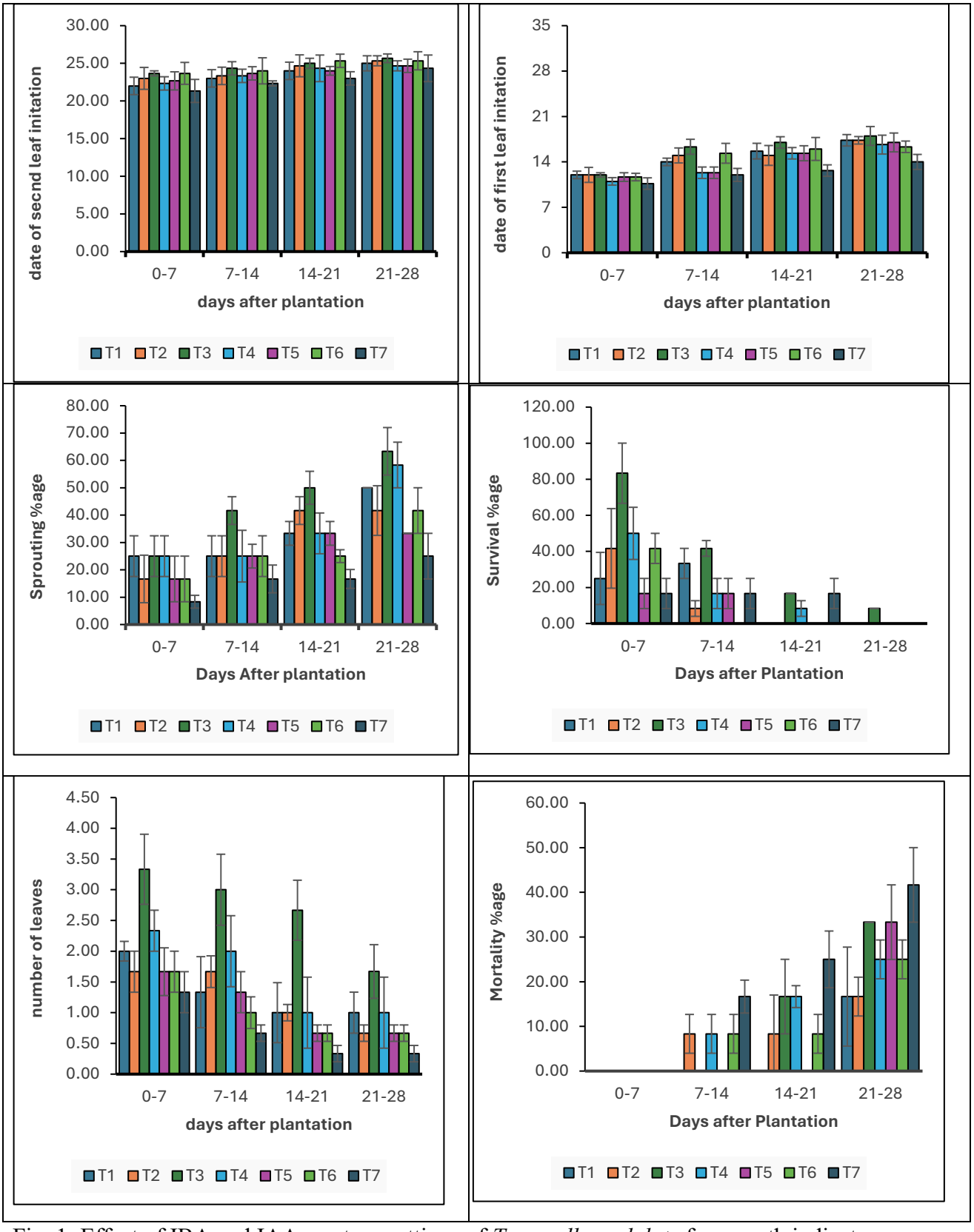


Fig. 1: Effect of IBA and IAA on stem cuttings of *Tecomella undulate* for growth indicators

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Number of leaves on cuttings

The number of leaves per cutting was recorded from the first initiation until the end of the experiment. Statistical analysis showed significant differences among treatments (Table 3). The trend was T3 > T1 ≥ T4 > T2 ≥ T5 ≥ T6 > T7. T3 (IAA 6000 ppm) produced the maximum number of leaves (1.67), followed by T1 and T4 (1.00 each). T2, T5, and T6 each produced 0.67 leaves, while the control (T7) recorded the lowest value (0.33) (Fig. 3). Previous studies also highlight the role of auxins in enhancing leaf production. For example, maximum leaf numbers were observed in *Psidium guajava* cuttings with 1000 ppm IBA (Kamboj *et al*. 2017), while it was also reported that 15–18 leaves were produced within 60 days under IBA application (Kakon *et al*. 2005 and Maurya et al. 2012). These comparisons confirm that auxin treatments can significantly improve leaf emergence in woody cuttings.

Table 3: Analysis of variance for the total number of leaves on cutting

Source	DF	SS	MS	F	P
Treatment	6	26.786	4.46429	4.24	0.0010**
Error	77	81.167	1.05411		
Total	83	107.952			

Grand Mean =1.3095 ; CV = 78.40

** = *significant* at $P \leq 0.01$ and NS = nonsignificant at $P \leq 0.05$, respectively.

Survival Percentage (%)

The number of surviving cuttings was counted at the end of the study and survival percentages were calculated. Statistical analysis showed non-significant differences among treatments (Table 4). The overall trend was T3 > T7 > T4 > T1 > T5 > T2 > T6. The highest survival (8.3 %) was recorded in T3 (IAA 6000 ppm) at 28 days after planting, followed by T7 and T4 (both 8.3–16.7 % at 14–21 days). Other treatments showed lower survival, with the minimum recorded in T6 at 7 days (Fig. 4). Compared with other species, the survival rates achieved here were low. Earlier studies reported much higher survival under auxin treatments—for example, it was found that 63–67 % survival was achieved with IBA or NAA (Paul and Aditi 2009), and 100 % survival was achieved in guava air-layers with IBA plus rooting medium (Shrivastava 2000). These differences highlight the need to optimize hormone concentrations and propagation conditions to improve the survivability of *T. undulata* cuttings.

Table 4: Analysis of variance for survival percentage

Source	DF	SS	MS	F	P
Treatment	6	1815.5	302.579	0.55	0.7678 NS
Error	77	42291.7	549.242		
Total	83	44107.1			

Grand Mean =14.286 ; CV = 164.05

** = *significant* at $P \leq 0.01$ and NS = nonsignificant at $P \leq 0.05$, respectively.

Mortality percentage (%)

At 28 days after planting, all T. undulata cuttings were examined and found dead. Mortality percentages were calculated for each treatment. Statistical analysis showed non-significant differences among treatments (Table 5). The trend was T1 < T2 < T6 < T4 < T5 < T3 < T7. The lowest mortality (16.7 %) occurred in T1 (IAA 4000 ppm), with T2 showing the same value at 21 days. T6 and T4 both recorded 25.0 %, while T3 and T5 each had 33.3 %. The highest mortality (41.7 %) was observed in the untreated control (T7) (Fig. 5). Although earlier studies have reported high survival in guava air-layers under various auxin treatments (Abdullah *et al*. 2006; Bhagat *et al*. 1998; Hore and Sen 1991; Maurya *et al*. 2012), there is little published information on mortality rates. Our findings suggest that optimizing auxin concentrations and propagation conditions may help reduce mortality in *T. undulata* cuttings.

Table 5: Analysis of variance for mortality percentage

Source	DF	SS	MS	F	P
Treatment	6	1131.0	188.492	0.60	0.7331 NS
Error	77	24375.0	316.558		
Total	83	25506.0			

Grand Mean =11.310 ; CV = 157.32

** = *significant* at $P \leq 0.01$ and NS = non-significant at $P \leq 0.05$, respectively.

Root formation

At 28 days after planting, all *T. undulata* cuttings were examined and none had survived. Uprooting confirmed that no adventitious roots had developed in any treatment. Although T3 (IAA 6000 ppm) produced the best sprouting and survival, it did not induce rooting. Published reports similarly note poor rooting under certain auxin treatments. No effect of 10 µM IAA on rooting of *Pisum sativum* cuttings (Eliasson and Areblad 1984); no rooting in *Ficus benjamina* with 10 ppm IAA or IBA (Topacoglu *et al*. 2016); and only 4 % rooting success in semi-hardwood *Psidium guajava* cuttings with 6000 ppm IBA (Khattak et al. 1983). 11 % rooting success of *T. undulata* via air layering (Kaur *et al*. 2019), and no root formation in *Salvadora oleoides* under IBA or NAA (Martin et al. 2011). Roots are critical for anchorage and resource uptake (Hartmann et al., 2014); thus, the absence of rooting likely caused the drying and death of cuttings in the present study. Further research is needed to identify effective auxin concentrations and propagation methods for conserving this economically important arid-zone timber species.

4. Discussion

Tecomella undulata is a multipurpose tree species of the arid zones of indian subcontinent. The tree is susceptible to drought and it has fire-resistant properties with high-quality timber. Due to its unique and valuable properties, the plant is being overexploited. Now, the plant is included in the list of threatened species as *T. undulata* possesses very poor regeneration with sluggish growth. Conservation strategies for *T. undulata* are being made to produce multiple copies to conserve this valuable tree species. The present study was also carried out for the conservation purpose of *T. undulata*. No rooting was observed during the present experiment and the results were non-significant.

For the development of roots in the marcopropagation system, several factors could be responsible for root initiation in *T. undulata*. These factors could be: rooting substrate, cofactors, genotypic effect, concentration of auxins, time of harvesting of cuttings, plantation time of cuttings, environmental imbalancing and locality, etc. Here, each factor will be discussed to find a way out to conserve *T. undulata*.

Combined effect of rooting substrate and auxins on root formation

It was reported in a study that the highest number of roots per cutting, maximum average length of roots, stem elongation, average maximum number of branches and number of sprouted leaves were obtained by the application of 100 ppm IBA with vermiculite substrate in tip cuttings of *C. erectus* as compared to the other rooting substrates and the control group (Abdel-Rahman 2020; Yasin *et al*., 2024). In the present study, no rooting substrate was used to influence the rooting. More shoots per stem cutting of *Warburgia ugandensis* by the combined effect of IBA and milled pine bark as compared with IBA alone and control (Florence *et al.* 2011). Highest survival percentage and improved morphological characters of guava cutting grown in rooting media and treated with IBA (Singh 2017). Highest survival percentage, maximum root formation and maximum number of shoots sprouted in minimum days in stem cuttings of *Momordica dioica* by the application of 1000 ppm of IBA and propagated in soil, sand & farm yard manure as rooting media (Padekar *et al.* 2018).

Rooting substrate or rooting media has all the necessary nutrients for root initiation and further growth of stem cuttings. In the present investigation, no rooting media was used to assist the auxins for root development. As the cuttings were planted in sand and no rooting media was added, the above-mentioned research was the evidence that root initiation could be better and faster if any of the rooting media is used with a suitable concentration of auxins.

Cofactors accelerate the effect of auxins

Better development of adventitious roots in cuttings was associated with total Phenol content, which acts as a cofactor for auxin. Low content of phenols resulted in poor root growth (Khandan Mirkohi *et al.,* 2015; Rehman *et al*., 2025). Combined effect of IBA and cofactors on stem cuttings of olive for rooting and after that, survival of these cuttings was better than the effect of IBA alone (Wiesman and Lavee 1994). In the present study, no assisting cofactor was used to promote rooting in *T. undulata* stem cuttings. Some of the chemicals, like total phenol content, act as a cofactor in the activity of auxins. In the present study, it could be assumed that the auxins needed a cofactor for their better performance, but that particular cofactor was missing, which is why root development was not obtained.

Genotypic effect on rooting

The 99% sprouting percentage, along with 48.1% embryonic root development and 10.4% rooting response in genotype no. 9 of *T. undulata*, these results were totally different and highly comparable with all *T. undulata* trees of different genotypes. The remaining genotypes showed the least results. According to the results of the experiment, it could be said that there is a severe effect of the genotypes of the species on its rooting. According to the above-mentioned study,

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different genotypes of *T. undulata* have different ability of rooting and these genotypes respond to auxins accordingly (Tyagi *et al.* 2011). In the present study, harvesting of stem cuttings was done only from one genotype and no rooting was observed. Thus, the effect of genotype on the rooting of *T. undulata* is understandable and other genotypes should be tested for rooting.

Effect of auxin concentration

Pisum sativum stem cuttings showed a positive rooting response with 100 μM IAA, while results were negative when 10 μM IAA was applied. Thus, the concentration of auxins had a significant effect on the rooting of cuttings (Eliasson and Areblad 1984). An 8000 ppm concentration of IBA was found most suitable for the cuttings of *Warburgia ugandensis* (Akwatulira *et al.* 2011), while on the other hand, the same concentration of 8000 ppm of IBA had negative effects on the cuttings of *Ulmus panifolia* (Griffin and Schroeder, 2004). Highest rooting percentage in *T. undulata* with IBA at a concentration of 6000 ppm, which was 35.72%, while IBA at a concentration of 4000 ppm showed negative results (Kaur *et al.* 2019).

Auxins should be used very precisely, as it was reported that lower concentrations and higher concentrations of auxins have a negative effect on root formation and growth of cuttings, was deteriorated. Now, the present investigation might have faced the effect of auxin concentration, as no root development was observed. Some other auxin concentrations are to be used for the mass multiplication and conservation of *T. undulata*.

Effect of the time of harvesting of cuttings

Rooting in *T. undulata* in two different seasons. The first phase of the experiment was carried out from July to December and the second phase of the experiment was carried out from January to March. So, the harvesting of stem cuttings of *T. undulata* was done in the months of January and July. Cuttings that were harvested during January produce roots, while cuttings harvested during July produce no roots (Tyagi *et al.* 2011; Aziz *et al*., 2021). Cuttings of *T. undulata* harvested during late winter showed better rooting than the cuttings harvested during late autumn due to the effect of IBA and NAA (Karami and Salehi 2010). Previous research on *T. undulata* clearly showed that cuttings harvested during the month of July exhibited no rooting. On the other hand, it was reported that cuttings harvested during the late winter showed positive results. Now, during the present investigation, cuttings were harvested during the month of November and then planted. No rooting was observed during the present investigation and the same response was reported by other researchers.

Effect of the time of plantation of cuttings

From January to March (late winter) was found to be the most suitable time for root development, which was 15%. From July to December, no root initiation was observed (Tyagi *et al.* 2011). In the present study, cuttings were planted in November and no rooting was observed; thus, it could be assumed that winter is not suitable for mass multiplication of *T. undulata*. There is another piece of evidence that the rooting ability of cuttings is highly season-dependent. Time of harvesting and then plantation of cuttings are almost the same, as cuttings cannot survive for longer periods after being harvested, unlike seeds could be stored for longer periods. So, the time of harvesting of cuttings had a significant effect on the rooting ability. Cuttings that were planted during the months of July-December showed a non-significant response on rooting, while the cuttings planted during the months of January-February showed a significantly positive rooting response (Karami and Salehi 2010). The present investigation was carried out during the month of November and no rooting was observed. It could be assumed that no rooting during November might be due to a fall in temperature, as positive rooting was observed when cuttings were planted during the month of January, when the temperature became relatively higher. Now it could be concluded that for mass multiplication of *T. undulata,* cuttings should be planted at the start of the spring season.

Sudden variations in weather and environment are always destructive. Sudden fall in temperature, unpredictable rainfall, floods, extra sunshine etc. are some of the major and practical issues that can severely damage the sensitive experiments conducted outside of the lab. These astonishing factors can never be neglected and their happening became hard to control. So, during the nursery experiments, these unexpected environmental factors should be kept in mind.

All the previous work on *T. undulata* was done in various districts of India. Very little research work was done in Pakistan. A lot of factors related to the locality can effect on germination of seeds and the sprouting of cuttings of any plant. It is very normal to say that climatic, topographic and environmental factors from country to country vary to a great extent. So the investigations that were carried out in Indian districts, the results of these investigations might be changed when they took place in Pakistan, due to the variations in several factors.

5. Conclusion

Macropropagation of *Tecomella undulata* stem cuttings using IAA and IBA under the tested conditions (loamy sand with farmyard manure) did not induce adventitious rooting. However, IAA at 6000 ppm enhanced sprouting, leaf emergence and short-term survival compared with other treatments. These results confirm that while auxins can stimulate initial shoot activity, they are insufficient alone to achieve successful clonal propagation of this threatened arid-zone tree. To conserve

and sustainably utilize *T. undulata*, future work should focus on identifying optimal auxin concentrations and combinations, testing multiple genotypes, and refining the timing of cutting, harvesting, and planting. Integrating suitable rooting substrates, cofactors and environmental control may help overcome the species' poor rooting response and enable development of a reliable mass-propagation protocol.

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