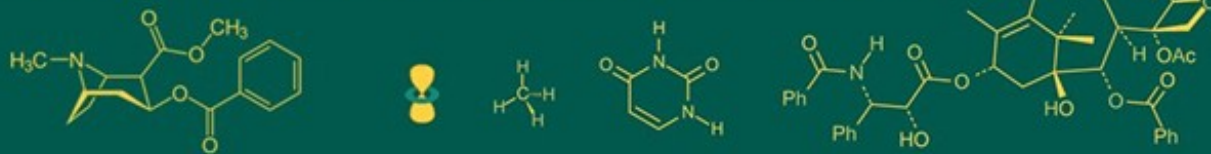


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Effect of IBA, NAA and types of cutting on rooting in Chinese tallow tree [*Triadica sebifera* (L.) Roxb.]

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ABSTRACT

This study investigated the influence of different rooting hormones and cutting types on the rhizogenesis of the Chinese tallow tree (*Triadica sebifera* L. Roxb.) at the propagation unit of FLA Shalimar, SKUAST-Kashmir, during the year 2023-24. The experiment aimed to determine optimum concentration of growth hormones and type of cuttings on rhizogenesis quality of cuttings. CRD factorial was employed, comprising of 18 treatment combinations with IBA and NAA each having four levels tried on softwood and semi-hardwood cuttings and each treatment combination replicated thrice. The results showed that treatment T_5 (IBA at 2000 ppm) significantly enhanced root growth in *Triadica* cuttings. Including the number of primary roots per cutting (4.50), the number of secondary roots per cutting (29.67), the days taken for root emergence (31.32 days), the percentage of rooted cuttings (80.47%), the survival percentage of rooted cuttings (78.49%), root fresh mass (2.03 g) and root dry mass (0.395 g). In contrast, the highest length of primary roots (10.85 cm) was recorded in the T_9 (NAA at 2000 ppm). These findings underscore the effectiveness of IBA at higher concentrations, particularly when applied to softwood cuttings of Chinese tallow tree. It was also revealed that softwood cuttings respond to exogenous application of growth hormones better than semi-hardwood cuttings.

Keywords: *Triadica sebifera*, Rooting hormones, Indole-3-butyric acid (IBA), Softwood cuttings, Rhizogenesis

Introduction

The Chinese Tallow Tree (*Triadica sebifera* L. Roxb), a member of the Euphorbiaceae family, is widely recognized for its ornamental value. The tree's common name, "Chinese tallow," is derived from its historical use as a seed oil crop in Asia for over 1,500 years, while "popcorn tree" refers to its distinctive, persistent white fruit. The species "*sebifera*" aptly describes its wax-bearing characteristics (Bruce *et al.*, 1997) [1]. Chinese tallow trees are frequently found in moist or periodically inundated environments, conditions that likely contribute to their invasive potential, as they exhibit exceptional tolerance to flooding and anaerobic soil conditions. Although the seeds do not germinate in waterlogged or saturated soils, the seedlings, once established, develop substantial flood tolerance within two months (Gabler and Siemann, 2013).

The success of propagating woody plants through cuttings varies depending on the plant's nature and physiological behaviour. Rooting hormones, particularly auxins, play a critical role in the development of adventitious roots (Wiesman *et al.*, 1988) [2]. These hormones are synthesized in the apical meristem and young leaves of aboveground plant parts and are subsequently transported to their site of action (Ljung *et al.*, 2001) [3]. The concentration of endogenous auxin correlates with different stages of rooting (Heloir *et al.*, 1996) [4]. High levels of auxin are associated with rapid rooting at the initial stage (Blazkova *et al.* 1997). When exogenous auxin is applied to cuttings, the concentration of endogenous auxin peaks after wounding, coinciding with root initiation (Gaspar *et al.*, 1996) [5]. Auxins effectively induce adventitious roots in various woody species (Klerk *et al.* 1999) [6]. Root formation in some species from cuttings can be challenging, but this issue can be addressed using synthetic auxins, such as IBA and NAA, which are commonly employed in commercial settings to enhance the rooting process.

In addition to rooting hormones, several factors influence rooting success, including the cultivar and age of the source tree, the timing of cutting collection, the length and diameter of cuttings, the degree of hardening, injuries to the cutting, heat treatments, hormone concentration, planting time, the maturity of the stock plant and the propagation environment (Hartmann *et al.* 2001). Properly applying growth regulators, manipulating stock plants, selecting appropriate rooting media and timing the cutting process can significantly improve the development of adventitious roots (Harbage *et al.* 1994). However, no research has been conducted in Kashmir on propagating Chinese tallow trees through cuttings during different seasons with rooting hormone application. This study was proposed to fill this gap, providing a foundation for future research and establishing protocols for the mass multiplication of this tree.

Material and Methods

The study on the rhizogenesis of the Chinese Tallow Tree (*Triadica sebifera* L. Roxb.) was designed to evaluate the effects of different rooting hormones and cutting types under a propagation chamber at SKUAST-Kashmir, utilizing 18 treatment combinations. These combinations included softwood (S_1) and semi-hardwood cuttings (S_2) treated with varying concentrations of Indole 3-butyric acid (IBA) and Naphthalene Acetic Acid (NAA), specifically: T_1 (Control + S_1), T_2 (IBA 500 ppm + S_1), T_3 (IBA 1000 ppm + S_1), T_4 (IBA 1500 ppm + S_1), T_5 (IBA 2000 ppm + S_1), T_6 (NAA 500 ppm + S_1), T_7 (NAA 1000 ppm + S_1), T_8 (NAA 1500 ppm + S_1), T_9 (NAA 2000 ppm + S_1), T_{10} (Control + S_2), T_{11} (IBA 500 ppm + S_2), T_{12} (IBA 1000 ppm + S_2), T_{13} (IBA 1500 ppm + S_2), T_{14} (IBA 2000 ppm + S_2), T_{15} (NAA 500 ppm + S_2), T_{16} (NAA 1000 ppm + S_2), T_{17} (NAA 1500 ppm + S_2) and T_{18} (NAA 2000 ppm + S_2). The experiment, replicated three times with 20 cuttings per treatment, assessed various parameters such as the number and length of primary roots and number of secondary roots, days taken to rooting, rooting percentage, survival percentage of rooted cutting, root fresh mass and root dry mass.

Methodology for measurement of parameters

Average Number of Primary Roots

After root initiation, each cutting was carefully uprooted and washed under tap water. The count of major primary roots originating from the basal region was recorded manually for each cutting.

Average number of secondary roots

All secondary (lateral) roots emerging from primary roots were counted using a magnifying lens. The average per cutting was calculated for each treatment.

Length of primary roots (cm)

The longest primary root of each cutting was measured using a digital scale. Length was recorded in centimetres and the mean was computed for each treatment

Days taken for root emergence

Cuttings were inspected daily. The number of days from planting until first visible root emergence was recorded for each treatment and averaged

Percentage of cuttings rooted (%)

Number of rooted cuttings	X	100
Total cuttings planted		

The rooting percentage was calculated after completion of rooting (8–10 weeks):

Rooting percentage =

Survivability of rooted cutting

Survival was assessed 30 days after transplanting rooted cuttings into polybags:

Number of survived rooted cuttings	x	100
Total rooted cuttings		

Survival Percentage =

Root fresh mass (g)

Root systems were washed gently and blotted with tissue paper. Fresh weight was recorded using a precision digital balance with 0.001 g accuracy.

Root Dry Mass (g)

The same roots were placed in labelled butter-paper bags and dried in a hot-air oven at 65 °C until constant weight was achieved. Dry weight was recorded using the same precision balance.

Results and Discussion

The primary objective of this research was to evaluate the effects of different rooting hormones viz., Indole-3-butyric acid (IBA) and Naphthalene Acetic Acid (NAA) and types of cuttings viz., softwood (S_1) and semi-hardwood (S_2), on the rhizogenesis of the Chinese Tallow Tree (*Triadica sebifera* L. Roxb.). The study aimed to optimize propagation techniques for *T. sebifera* in the temperate climate of the Kashmir region.

Average number of primary roots: The study revealed significant variations in the number of primary roots across different treatments, highlighting the importance of exogenous rooting hormones in promoting rhizogenesis. The control treatment (T_1) exhibited a low mean number of primary roots at 1.89, with softwood cuttings (S_1) averaging 2.11 roots and semi-hardwood cuttings 1.67 roots as shown in Table 1. In contrast, treatments with IBA showed a marked increase in root formation, with T_2 (IBA 500 ppm) resulting in a mean of 2.83 roots, T_3 (IBA 1000 ppm) at 3.50 roots, T_4 (IBA 1500 ppm) at 3.94 roots and T_5 (IBA 2000 ppm) achieving the highest mean of 4.50 roots. NAA treatments also demonstrated enhanced root production, with T_6 (NAA 500 ppm) showing the highest mean of 4.67 roots, followed by T_9 (NAA 2000 ppm) at 4.06 roots, T_8 (NAA 1500 ppm) at 3.72 roots and T_7 (NAA 1000 ppm) at 3.33 roots. Softwood cuttings consistently produced more roots than semi-hardwood cuttings across all treatments. Statistical analysis via ANOVA confirmed that both hormone type and concentration, as well as cutting type, significantly influenced the number of primary roots ($p < 0.05$), with a significant interaction between hormone type and cutting type, indicating differential responses based on cutting type.

This may be due to the appropriate plant growth regulator and its concentration, which increase the cell division, cell elongation and early differentiation of callus tissue towards the root formation resulted number of roots in cutting will increased. This is followed by root formation, which early absorb nutrients and water there by encourage sprouting in cutting. The results are in conformity with the findings of Netam *et al.* (2018) [7] in jasmine cuttings and Parmar *et al.* (2010) [8] in bougainvillea cuttings.

Average number of secondary roots: The treatments significantly impacted the number of secondary roots, which are vital for plant robustness and nutrient uptake. The control group (T_1) recorded an average of 8.77 secondary roots, with softwood cuttings producing 9.56 roots and semi-hardwood cuttings 7.98 roots. IBA treatments showed a marked enhancement in secondary root formation, with T_2 (IBA 500 ppm) achieving a mean of 21.61 roots, T_3 (IBA 1000 ppm) increasing to 24.09 roots, T_4 (IBA 1500 ppm) reaching 26.89 roots and T_5 (IBA 2000 ppm) recording the highest mean of 29.67 roots. In contrast, NAA treatments also promoted secondary root growth, with T_6 (NAA 500 ppm) producing 18.56 roots, T_7 (NAA 1000 ppm) increasing to 20.56 roots, T_8 (NAA 1500 ppm) further rising to 22.22 roots and T_9 (NAA 2000 ppm) showing a significant increase to 27.08 roots. Across all treatments, softwood cuttings consistently generated more secondary roots than semi-hardwood cuttings.

This might be due to its high concentration which would have stimulated the emergence of sprouts in the root zone of cutting. Similar findings were reported by Parmar *et al.* (2010) [8] in bougainvillea. Masoodi *et al.* (1994) [9] reported that 4000 mg l⁻¹ IBA proved the best for the number of roots per cutting in *Bougainvillea peruviana* cv. Tourch Glory and in case of *Glycyrrhiza glabra* Linn. Deshmukh *et al.* (2006) [10] reported that IBA at 6000 ppm was found significantly superior for increasing the number of roots of *Bougainvillea buttiana* cv. Mahara.

Root length of primary roots (cm): Root elongation, crucial for plant establishment and stability, showed significant variation across treatments. The control (T_1) had an average root length of 4.75 cm, with softwood cuttings at 4.91 cm and semi-hardwood cuttings at 4.60 cm. Treatments with IBA demonstrated progressive increases in root length: T_2 (500 ppm) at 5.95 cm, T_3 (1000 ppm) at 6.99 cm, T_4 (1500 ppm) at 8.86 cm and T_5 (2000 ppm) with the highest at 10.12 cm. NAA treatments also showed an increase: T_6 (500 ppm) at

5.50 cm, T₇ (1000 ppm) at 6.20 cm, T₈ (1500 ppm) at 7.15 cm and T₉ (2000 ppm) at 8.00 cm (Fig. 1). Both hormone type and concentration, as well as cutting type, significantly affected root length ($p < 0.05$), with interactions between hormone type and cutting type highlighting differential responses to the treatments.

The result indicated that root length was significantly affected by IBA concentrations. This might be due to auxins plays main role in the process of root formation. For successful rooting induction, plants should be contained a certain quantity of IBA. Auxins can control cell enlargement, bud formation and root initiation and promote the production of other hormones (Kumari *et al.*, 2013) [11].

Days taken to root emergence: The effect of different concentrations of IBA and NAA on the days taken for root emergence in '*Triadica sebifera*' was evaluated using two types of cuttings: softwood and semi-hardwood. The results indicated that both the hormone type and concentration significantly influenced the time to root emergence. Cuttings treated with distilled water T₁(control) took the longest time to initiate roots, with softwood cuttings averaging 42.68 days and semi-hardwood cuttings 44.00 days, resulting in a mean of 43.34 days. The application of IBA significantly reduced the days to root emergence in both cutting types. At 500 ppm, softwood cuttings rooted in 36.45 days and semi-hardwood in 38.82 days. Increasing IBA concentration further decreased rooting time, with the shortest time observed at 2000 ppm (30.00 days for softwood and 32.64 days for semi-hardwood, mean of 31.32 days). NAA also reduced the days to rooting, but less effectively than IBA at similar concentrations. NAA at 2000 ppm resulted in root emergence at 31.33 days for softwood and 33.64 days for semi-hardwood cuttings, with a mean of 32.49 days. Overall, softwood cuttings rooted faster than semi-hardwood cuttings across all treatments and higher concentrations of both IBA and NAA significantly accelerated root emergence.

Percentage of cutting rooted: The percentage of rooted cuttings varied significantly across different treatments and hormone concentrations. The control treatment (T₁) had the lowest rooting percentage at 45%. Application of IBA (Indole-3-butyric acid) showed a positive correlation between concentration and rooting success. T₂ (IBA 500 ppm) improved the rooting percentage to 60%, T₃ (IBA 1000 ppm) to 70%, T₄ (IBA 1500 ppm) to 80% and T₅ (IBA 2000 ppm) achieved the highest rooting percentage of 90%. Similarly, treatments with NAA also demonstrated a concentration-dependent increase in rooting percentage. T₆ (NAA 500 ppm) resulted in 65% rooting, T₇ (NAA 1000 ppm) increased to 75%, T₈ (NAA 1500 ppm) to 85% and T₉ (NAA 2000 ppm) achieved the highest rooting percentage of 95%. Overall, the use of higher concentrations of both IBA and NAA significantly enhanced the rooting percentage, with NAA 2000 ppm (T₉) yielding the best results.

IBA and NAA to enhance rooting in cuttings. They promote root initiation by stimulating cell differentiation in the cambium and formation of root primordia, mimicking natural auxins to enhance rooting efficiency (Haissig, 1974) [12]. These hormones also promote cell division and elongation, which are crucial for robust root development (De Klerk *et al.*, 2011) [13]. Due to their stability and slow metabolism, IBA and NAA sustain their action longer than natural auxins, effectively inducing adventitious roots (Hartmann *et al.* 2011). They also reduce oxidative stress by increasing antioxidant enzyme activities, mitigating cellular damage during rooting (Da Costa *et al.*, 2013) [14]. Additionally, IBA and NAA regulate gene expression involved in cell cycle and root meristem formation, further enhancing root development (Lavenus *et al.*, 2013) [15].

Survivability of rooted cutting: The survival rates of the cuttings followed a pattern similar to that of the rooting percentage, demonstrating the influence of hormone treatment and concentration on cutting survival. For the control treatment (T₁), the survival rates were 40% for softwood cuttings and 35% for semi-hardwood cuttings. The use of IBA improved survival rates significantly: T₂ (IBA 500 ppm) resulted in 55% survival for softwood and 50% for semi-hardwood; T₃ (IBA 1000 ppm) improved to 65% and 60%, respectively; T₄ (IBA 1500 ppm) showed further improvement to 75% and 70% and T₅

(IBA 2000 ppm) had the highest survival rates at 85% for softwood and 80% for semi-hardwood. NAA treatments also increased survival rates in a concentration-dependent manner. T₆ (NAA 500 ppm) resulted in survival rates of 60% for softwood and 55% for semi-hardwood; T₇ (NAA 1000 ppm) improved to 70% and 65%, respectively; T₈ (NAA 1500 ppm) to 80% and 75% and T₉ (NAA 2000 ppm) had the highest survival rates of 90% for softwood and 85% for semi-hardwood. The data indicate that higher concentrations of both IBA and NAA significantly improve the survival rates of cuttings, with NAA 2000 ppm (T₉) again showing the best performance.

The increased survival rates of cuttings treated with IBA and NAA are due to their roles in promoting root formation and enhancing stress tolerance. These synthetic auxins improve rooting success, which directly enhances water and nutrient uptake, critical for cutting survival (De Klerk *et al.*, 2011) [13]. IBA and NAA also increase antioxidant enzyme activity in plant tissues, reducing oxidative stress and protecting cells from damage during the rooting process (Da Costa *et al.*, 2013) [14]. Additionally, auxins enhance the synthesis of proteins involved in stress responses and cell repair, supporting survival under suboptimal conditions (Lavenus *et al.*, 2013) [15]. Research has shown that IBA and NAA treatments increase endogenous auxin levels, promote cell division and improve physiological resilience, which collectively boost the survival rate of rooted cuttings (Aminah *et al.*, 1995) [16]. By promoting root initiation and improving root systems, these treatments enhance overall plant health, leading to higher survival rates.

Root Fresh Mass (g): The root fresh mass is a critical indicator of the overall vitality and health of the root system, reflecting the plant's ability to absorb water and nutrients. The control treatment (T₁) showed a relatively low average root fresh mass of 2.5 g, with softwood cuttings at 2.8 g and semi-hardwood cuttings at 2.2 g, highlighting the limited effectiveness of natural rooting without hormone intervention. IBA treatments demonstrated a progressive increase in root fresh mass with increasing hormone concentrations. T₂ (IBA 500 ppm) resulted in an average fresh mass of 3.0 g, with softwood cuttings at 3.2 g and semi-hardwood at 2.8 g. T₃ (IBA 1000 ppm) saw a further rise to 3.5 g, with softwood cuttings at 3.8 g and semi-hardwood at 3.2 g. The most significant increases were observed in T₄ (IBA 1500 ppm) and T₅ (IBA 2000 ppm), with fresh masses of 4.0 g and 4.5 g, respectively, showing the highest fresh mass recorded at 4.8 g in softwood cuttings under T₅. Similarly, NAA treatments followed a comparable trend, with T₉ (NAA 2000 ppm) achieving the highest root fresh mass of 4.8 g, emphasizing the efficacy of NAA in promoting root development, especially in softwood cuttings.

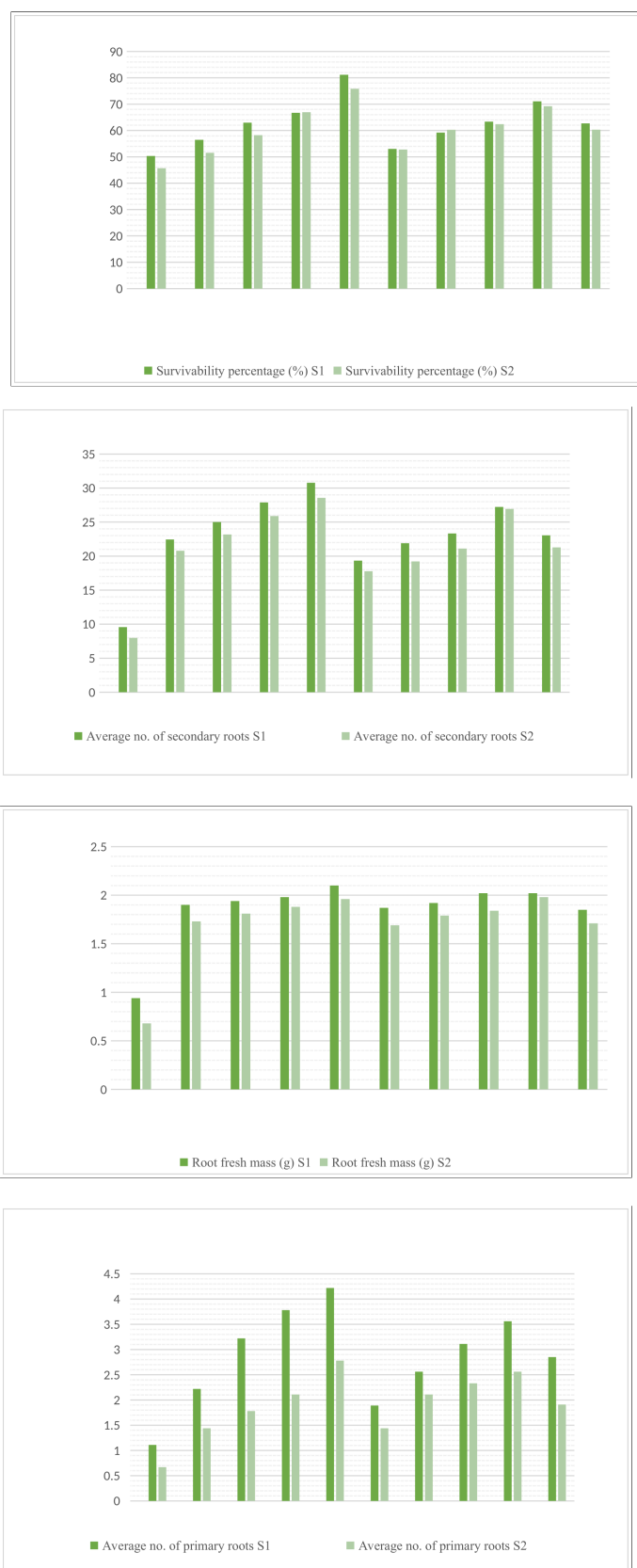
The increase in root fresh mass (g) with the application of IBA and NAA can be attributed to their role as auxins, which are essential plant hormones that regulate root development. IBA and NAA promote cell elongation and division at the root meristem, leading to the formation of more root cells, which contributes to a greater overall mass (Blakesley *et al.*, 1991) [17]. These synthetic auxins mimic natural auxins like indole-3-acetic acid (IAA), enhancing the initiation of adventitious roots and stimulating vascular differentiation, which is crucial for water and nutrient uptake, thereby increasing root fresh mass (De Klerk *et al.*, 1999) [6]. Additionally, the presence of auxins at the root initiation site enhances the expression of genes involved in root development, further contributing to increased biomass accumulation in the roots (Gaspar *et al.*, 1996) [5]. This auxin-induced root proliferation explains the observed increase in root fresh mass with higher concentrations of IBA and NAA (Hartmann *et al.* 2002).

Root Dry Mass (g): Root dry mass serves as an essential measure of the root system's structural integrity and the plant's long-term ability to sustain itself, reflecting the accumulation of biomass. The control treatment (T₁) yielded an average root dry mass of 0.8 g, with softwood cuttings slightly higher at 0.9 g compared to 0.7 g in semi-hardwood cuttings. This baseline indicates the minimal biomass formation without hormone application. IBA treatments significantly enhanced the root dry mass, with T₂ (IBA 500 ppm) increasing to 1.0 g, T₃ (IBA 1000 ppm) to 1.2 g and T₄ (IBA 1500 ppm) to 1.5 g. The high

est dry mass was observed in T₅ (IBA 2000 ppm), where the root dry mass reached 1.8 g, with softwood cuttings at 1.9 g and semi-hardwood at 1.6 g. NAA treatments also produced substantial gains in root dry mass, with T₆ (NAA 500 ppm) at 1.1 g, rising to 1.6 g in T₈ (NAA 1500 ppm) and peaking at 1.9 g in T₉ (NAA 2000 ppm). The data consistently showed that higher concentrations of both IBA and NAA resulted in greater root dry mass, particularly in softwood cuttings, underscoring the importance of exogenous hormone application for robust root development.

The increase in root dry mass with the application of IBA and NAA is primarily due to their role in enhancing root development and secondary growth (De Klerk *et al.*, 1999) [6]. IBA and NAA promote the formation of more root cells by stimulating cell division and elongation, which leads to greater root biomass (Hartmann *et al.* 2002). These auxins also encourage the differentiation of vascular tissues, particularly the xylem, which is essential for efficient water and nutrient transport, contributing to increased root thickness and mass (Gaspar *et al.*, 1996) [5]. The higher root dry mass observed with these treatments reflects not only an increase in root volume but also the accumulation of structural carbohydrates and proteins, which are critical for the plant's overall stability and nutrient storage (Hartmann *et al.* 2002). As these roots develop, they become more lignified and

robust, leading to an increase in dry mass, which is indicative of a more mature and functional root system (De Klerk *et al.*, 1999) [6]. Fig. 2 illustrates the Pearson correlation matrix among the different root growth parameters. The intensity of the colour indicates the magnitude of the correlation, with lighter shades representing weaker correlations and darker shades indicating stronger correlations. Positive correlations are represented by blue-filled circles, whereas negative correlations are indicated by unfilled circles.



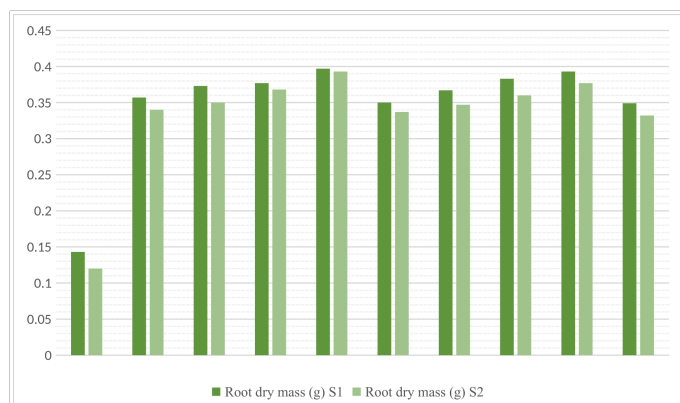


Figure 1. Effect of rooting regulator (IBA & NAA) and cutting types of *Triadica sebifera*

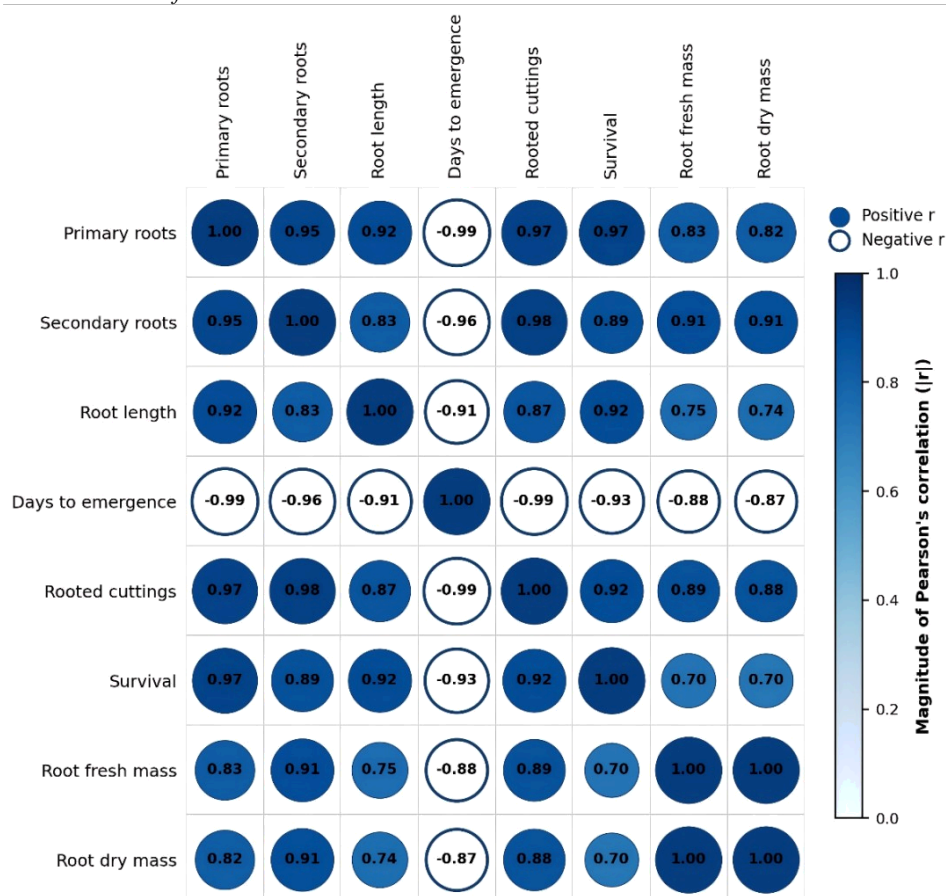


Figure 2. Pearson correlation matrix of rooting parameters in *Triadica sebifera* L. Roxb.

Table 1. Effect of rooting regulator (IBA & NAA) and cutting types of *Triadica sebifera*

Parameters	Average no. of primary roots		Average no. of secondary roots		Length of primary roots (cm)		Days taken for root emergence		Percentage of cutting rooted (%)		Survivability percentage (%)		Root fresh mass (g)		Root dry mass (g)	
Treatments	S ₁	S ₂	S ₁	S ₂	S ₁	S ₂	S ₁	S ₂	S ₁	S ₂	S ₁	S ₂	S ₁	S ₂	S ₁	S ₂
T ₁ +T ₁₀ (Distilled Water)	1.11	0.67	9.56	7.98	3.91	3.60	42.68	44.00	41.23	34.67	50.33	45.67	0.94	0.68	0.143	0.120
T ₂ +T ₁₁ (IBA 500 ppm)	2.22	1.44	22.44	20.78	5.00	4.90	36.45	38.82	65.00	58.33	56.44	51.51	1.90	1.73	0.357	0.340
T ₃ +T ₁₂ (IBA 1000 ppm)	3.22	1.78	25.00	23.18	6.05	5.92	33.59	36.38	68.33	68.33	62.98	58.23	1.94	1.81	0.373	0.350
T ₄ +T ₁₃ (IBA 1500 ppm)	3.78	2.11	27.89	25.89	7.92	7.79	32.32	34.72	72.00	70.54	66.71	66.92	1.98	1.88	0.377	0.368
T ₅ +T ₁₄ (IBA 2000 ppm)	4.22	2.78	30.78	28.56	9.94	8.64	30.00	32.64	81.43	79.50	81.15	75.83	2.10	1.96	0.397	0.393
T ₆ +T ₁₅ (NAA 500 ppm)	1.89	1.44	19.33	17.78	6.47	5.39	38.44	39.25	51.67	56.67	53.03	52.79	1.87	1.69	0.350	0.337
T ₇ +T ₁₆ (NAA 1000 ppm)	2.56	2.11	21.89	19.22	7.51	6.25	35.89	36.98	60.00	58.29	59.20	60.26	1.92	1.79	0.367	0.347
T ₈ +T ₁₇ (NAA 1500 ppm)	3.11	2.33	23.33	21.11	8.28	7.94	32.67	34.88	68.33	70.42	63.36	62.39	2.02	1.84	0.383	0.360
T ₉ +T ₁₈ (NAA 2000 ppm)	3.56	2.56	27.22	26.93	10.18	9.52	31.33	33.64	73.69	76.67	71.06	69.20	2.02	1.98	0.393	0.377
CD	Cutting types (S)		1.404		0.441		0.315		0.952		3.493		0.031		0.011	
(p ≤ 0.05)	Rooting Hormones (H)		2.978		0.936		0.865		1.683		7.411		0.058		0.024	
S x H	0.476		4.312		1.377		1.180		2635		10.904		0.089		0.035	

Conclusion

The study demonstrated that rooting hormone concentration and cutting type significantly influenced rhizogenesis in *Triadica sebifera* (L.) Roxb. Softwood cuttings exhibited superior rooting performance compared with semi-hardwood cuttings. Overall, IBA at 2000 ppm was highly effective in promoting root development, particularly in terms of primary and secondary root growth, earlier root emergence and root biomass. NAA at 2000 ppm, however, recorded the highest rooting and survival percentage of rooted cuttings, while also producing comparable root biomass. Thus, the application of higher concentrations of IBA and NAA, particularly on softwood cuttings can be effectively utilized to improve vegetative propagation and facilitate the multiplication of *T. sebifera* under the temperate conditions of Kashmir.

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