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Effects of Plant Growth Regulators and Covering Techniques on the Rooting and Growth of *Hibiscus tiliaceus* L. Stem Cuttings

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Abstract: This study was conducted to determine the effect of ZPT and Covering on the Growth of Indian Waru Stem Cuttings (*Hibbiscus Tiliaceus* L), conducted in Senenan Village, Tahunan District, Jepara Regency from July to September 2023. The study used a factorial experiment with a basic pattern of Completely Randomized Block Design (CRBD) consisting of two factors and three replications. The first factor is zpt (Z), consisting of 3 levels, namely Z0 (without zpt), Z1 (rapid root zpt), Z2 (root up zpt). The second factor is cover (S), consisting of 2 levels, namely S0 (without cover) and S1 (covered). The observed parameters included the percentage of cutting growth, time of shoot emergence, length and number of roots, length and number of shoots, fresh and dry weight of plants. The final results showed that the treatment of zpt was significantly different in the percentage of growth, time of shoot emergence, shoot length at 8 WAP, and the number of shoots at 10 WAP. The treatment of covering significantly differed in the time of shoot emergence, shoot length at 8 WAP, and the number of shoots at the ages of 4, 8, and 10 WAP. There was an interaction between the provision of PGR and covering on the percentage of shoot growth, time of shoot emergence, number of roots, shoot length at 8 WAP, and number of shoots at 8 and 10 WAP.

Keywords: Rapid root, Root up, Shade, Cuttings, Indian Waru

1. Introduction

Indian waru (*Hibiscus tiliaceus* L.) is a shade tree species that has long been recognized by Indonesian communities and is widely distributed across tropical regions. This species exhibits strong adaptability, including the ability to grow on marginal lands such as sandy soils and tidal areas (Sudjindro, 2007 cited in Aulya *et al*., 2020). In addition to its function as a shade plant, *H. tiliaceus* is commonly utilized as bonsai material due to its attractive trunk and canopy structure when properly managed. The species is relatively sturdy, resistant to breakage, possesses high aesthetic value, and contributes to air pollution absorption (Santoso *et al*., 2016). *H. tiliaceus* is a woody plant with high potential for bonsai cultivation; however, its natural population has become increasingly scarce. This condition highlights the need for effective propagation strategies, both generative and vegetative. Generative propagation faces several constraints, including limited seed availability due to susceptibility to insect pests and fungal infections, as well as low seed germination rates. Therefore, vegetative propagation is considered a more effective approach. Suwandi (2014) reported that vegetative propagation serves as an alternative regeneration method for plant species that are difficult to propagate through seeds, including *H. tiliaceus*.

One of the key factors influencing the success of vegetative propagation is the size of the planting material. In general, longer or larger cuttings tend to enhance plant establishment and growth performance (Hartmann *et al.,* 2010). However, plant species vary in their responses to cutting length; some species exhibit optimal rooting at lengths of 5–8 cm (OuYang *et al*., 2015), whereas others show better growth at cutting lengths of 15–25 cm (Aminah *et al*., 2015;

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Yusnita *et al*., 2018). Previous studies on stem cuttings, such as in breadfruit, have employed cutting lengths of 10 cm and 15–20 cm (Adinugraha & Wahyuningtyas, 2018). Nevertheless, *H. tiliaceus* is known to exhibit relatively low propagation success, both generatively and vegetatively. Therefore, additional treatments, particularly the application of plant growth regulators (PGRs), are required to stimulate shoot emergence and root system development.

Commonly used PGRs for promoting root formation include Rapid Root and Root Up. Rapid Root contains indole-3-butyric acid (IBA) and naphthaleneacetic acid (NAA), whereas Root Up contains NAA, m-NAA, IBA, and thiram. These compounds belong to the auxin group, which plays a crucial role in root induction. Pasetriyani (2013) stated that plant growth regulators are organic compounds naturally produced by plants that can influence physiological processes at low concentrations. The application of PGRs to stem cuttings aims to enhance nutrient reserves and hormonal supply, thereby improving cutting survival and growth. The use of Rapid Root has been reported to increase survival rates to approximately 80%, owing to its IBA and NAA content as well as the presence of fungicidal compounds. IBA and NAA are stable synthetic auxins that effectively provide optimal hormonal conditions for cutting development (Cahyadi *et al*., 2017). Khair *et al*. (2013) reported that the application of Root Up at appropriate concentrations increased cutting survival rates up to 93.33%, significantly higher than the control treatment, which achieved only 60%. However, PGR application must be carefully managed, as excessively high concentrations may lead to excessive cell division and callus formation, thereby inhibiting root and shoot development, while insufficient concentrations may fail to produce optimal effects.

In addition to PGR application, vegetative propagation through cuttings also requires the use of covering techniques. Covering serves to protect cuttings from direct rainfall, maintain air temperature and humidity around the cuttings, and reduce pest disturbances. Reduced light intensity under covering conditions can lower transpiration rates, thereby creating a more favorable microclimate for cutting growth. Hasibuan (2022) reported that covering creates ideal environmental conditions and significantly improves cutting survival rates. Similarly, Adisti *et al*. (2017) demonstrated that cuttings covered with transparent or red plastic exhibited higher survival percentages, plant height, and branch numbers compared to uncovered cuttings. Therefore, the application of covering techniques is strongly recommended to enhance the success of cutting propagation (Sahlim, 2023). Based on the above considerations, this study was conducted to evaluate the effectiveness of several commonly used plant growth regulators and to assess the impact of covering techniques on the growth performance of Indian waru stem cuttings (*Hibiscus tiliaceus* L.).

2. Methodology

2.1.1. Time and Location

The research was conducted from July to September 2023 in Senenan Village, Tahunan District, Jepara Regency, Indonesia, on a bonsai cultivation site.

2.1.2. Materials and Equipment

The equipment used included black plastic pots (20 cm in diameter), plastic covers, paranet shading nets, raffia string, wire, scissors, knives, an electronic balance, a camera, and other supporting tools. The materials consisted of stem cuttings of Indian waru obtained from 4–5-year-old mother plants, Malang sand, Gandasil D fertilizer, Rapid Root plant growth regulator, Root Up plant growth regulator, and water.

2.1.3. Research Method

The experiment employed a Randomized Completely Block Design (RCBD) with a two-factor factorial arrangement and three replications. The first factor was plant growth regulator (PGR/ZPT), consisting of Z0 (without PGR/control), Z1 (Rapid Root containing IBA and NAA), and Z2 (Root Up containing NAA, m-NAA, IBA, and thiram). The second factor was covering, consisting of S0 (without covering) and S1 (with covering). Six treatment combinations were applied (Z0S0, Z1S0, Z2S0, Z0S1, Z1S1, and Z2S1). Each treatment was replicated three times with five sample plants per experimental unit, resulting in a total of 90 experimental plants.

Prior to the experiment, the research area was cleared of weeds using herbicide. A shade structure measuring 4.20 × 2.70 m with a height of 2 m was constructed using wooden frames, equipped with paranet roofing and side nets to regulate light intensity, protect plants from direct rainfall, and maintain suitable temperature and humidity. The growing medium consisted of Malang sand, with coarse sand filled to half of each pot followed by fine sand to full capacity. Stem cuttings were obtained from healthy 4–5-year-old Indian waru plants, using branches approximately 2 cm in diameter and 15 cm in length. Cuttings were taken from the basal, middle, and apical portions of the branches. Rapid Root and Root Up were prepared according to the recommended dosage and applied to the basal ends of the cuttings according to the treatments. The cuttings were then planted in pots containing the sand medium. For the covered treatment, cuttings were enclosed with transparent plastic covers for 17 days after planting.

3. Observed Parameters

3.1 Cutting Survival Percentage

The survival percentage of stem cuttings was recorded at the end of the observation period (10 weeks after planting, WAP). Survival percentage was calculated using the following formula:

$$\text{Survival percentage (\%)} = \frac{\text{Number of surviving cuttings}}{\text{Total number of cuttings per block}} \times 100.$$

3.2 Time to Shoot Emergence

Time to shoot emergence was observed daily from planting until the appearance of the first shoot. Shoot emergence was indicated by the breaking of dormant buds.

3.3 Number of Roots

The number of roots was counted at 10 WAP by recording the total number of roots formed on each cutting.

3.4 Number of Shoots

The number of shoots was recorded starting from the initial emergence of shoots and subsequently observed weekly until 10 WAP. Only primary shoots were counted.

3.5 Fresh Weight of Shoots and Roots

Shoots were harvested, cleaned, and weighed using an electronic balance at 10 WAP to determine fresh shoot weight. Roots were cleaned of the growing medium and weighed using an electronic balance at 10 WAP to determine fresh root weight

3.6 Dry Weight of Shoots and Roots

Cleaned shoots were wrapped in paper and oven-dried at 80 °C for approximately 48 hours until constant weight was achieved. Dry shoot weight was measured using an analytical balance. Cleaned roots were wrapped in paper and oven-dried at 80 °C for approximately 48 hours until constant weight was achieved. Dry root weight was measured using an analytical balance.

4. Results and Discussion

4.1. Cutting Survival Percentage

The results showed that the application of plant growth regulators (PGRs) and covering treatments influenced the survival percentage of *Hibiscus tiliaceus* stem cuttings (Figure 1). In the treatment without cover (S0), the use of Rapid Root (Z1) resulted in the highest cutting survival percentage (73.33%), followed by Root Up (Z2) at 60.00%, while the control treatment without PGR (Z0) showed the lowest survival rate (20.00%). This indicates that exogenous PGR application plays a crucial role in enhancing the establishment and survival of stem cuttings, particularly under non-protected environmental conditions. This is in accordance with the research results of Anwar *et al* (2024), that PGPR is able to support the growth ability of plants.

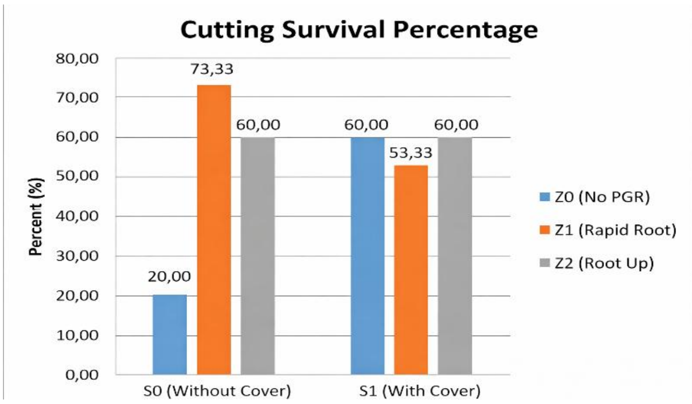

Fig. 1: Cutting Survival Percentage

The improved survival in Z1 and Z2 treatments is likely related to the presence of auxin-based compounds in commercial rooting hormones, which stimulate root initiation and development. Auxins promote cell division and differentiation at the cutting base, leading to faster root formation and improved water and nutrient uptake, ultimately increasing cutting viability.

Under the covering treatment (S1), survival percentages were more uniform across PGR treatments, ranging from 53.33% to 60.00%. The use of cover appeared to mitigate environmental stress, such as excessive solar radiation and moisture loss, thereby improving survival even in the absence of PGR (Z0). This suggests that covering creates a favorable microclimate by maintaining higher humidity and stable temperatures, which are essential for successful rooting and shoot development in stem cuttings.

The interaction between PGR application and covering indicates that while PGRs significantly enhance cutting survival, their effectiveness can be influenced by environmental modification. Under covered conditions, the benefit of PGR application becomes less pronounced, as the microclimate itself supports cutting survival. Similar findings have been reported in vegetative propagation studies, where both hormonal and environmental factors jointly determine cutting success.

4.2. Time to Shoot Emergence

The time of shoot emergence of *Hibiscus tiliaceus* stem cuttings was influenced by both plant growth regulator (PGR) application and covering treatment (Figure 2). Under non-covered conditions (S0), shoot emergence was fastest in cuttings treated with Rapid Root (Z1), while Root Up (Z2) showed the slowest response. This suggests differences in auxin formulation and uptake efficiency among PGR treatments, affecting early physiological activity and bud break.

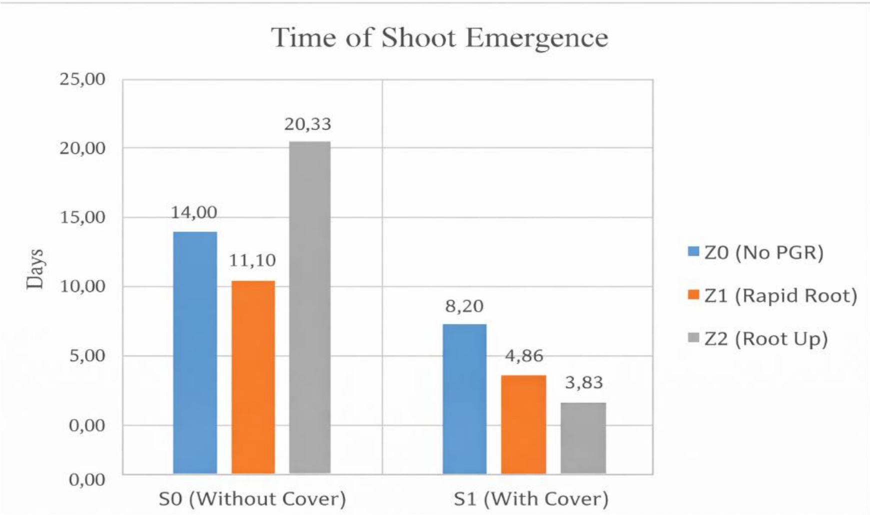

Fig. 2: Time to Shoot Emergence

Covering treatment (S1) significantly reduced the time required for shoot emergence across all PGR levels. The fastest shoot emergence was observed in Z2 under covered conditions, followed by Z1 and the control. The use of covering likely created a favorable microclimate by maintaining higher humidity, reducing transpiration, and stabilizing temperature, thereby enhancing metabolic processes and promoting faster shoot initiation.

The interaction between PGR application and covering indicates a synergistic effect on shoot emergence. PGRs support endogenous hormone balance and meristematic activity, while covering minimizes environmental stress, allowing hormonal effects to be expressed more effectively. Similar results have been reported in vegetative propagation studies, where auxin application combined with controlled microclimatic conditions accelerated shoot emergence and improved propagation efficiency.

Overall, the results highlight that covering plays a crucial role in accelerating shoot emergence, particularly when combined with appropriate PGR application, emphasizing the importance of integrating hormonal and environmental management in stem cutting propagation.

4.3. Number of Roots

The number of roots in *Hibiscus tiliaceus* stem cuttings was affected by both plant growth regulator (PGR) application and covering treatment (Figure 3). Under non-covered conditions (S0), cuttings treated with Rapid Root (Z1) produced the highest number of roots, indicating the effectiveness of auxin-based PGRs in stimulating root initiation. In contrast, the control treatment (Z0) resulted in the lowest root number, reflecting limited endogenous hormone activity.

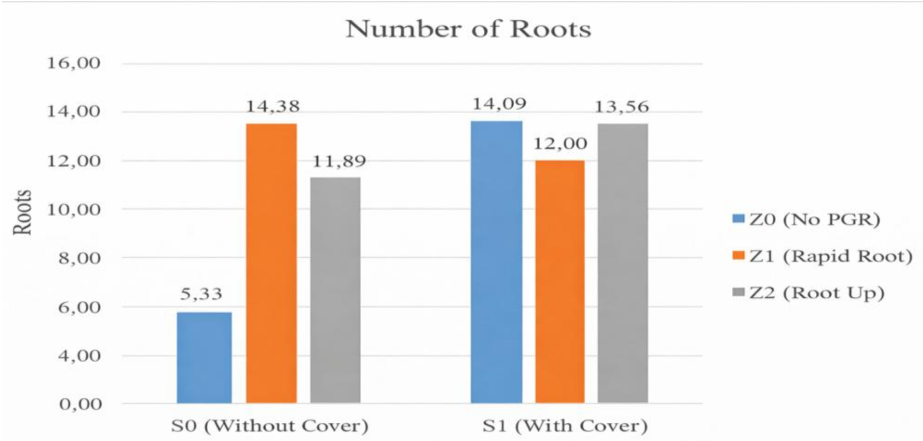

Fig. 3: Number of Roots

The application of covering (S1) increased root formation across all treatments. Even without PGR application, covered cuttings showed a marked increase in root number, highlighting the importance of favorable microclimatic conditions. Higher humidity and reduced transpiration under covering likely enhanced carbohydrate utilization and cell differentiation in the rooting zone.

The interaction between PGR and covering suggests a complementary effect, where auxin-induced root initiation is optimized under reduced environmental stress. These findings are consistent with previous studies reporting improved adventitious root formation through the combined management of hormonal treatment and microenvironment control.

4.4. Number of Shoots (shoots)

The number of shoots in *Hibiscus tiliaceus* stem cuttings was influenced by both plant growth regulator (PGR) application and covering treatment (Figure 4). Under non-covered conditions (S0), cuttings treated with Root Up (Z2) produced a higher number of shoots compared to Rapid Root (Z1) and the control, indicating that the combination of auxins in Root Up effectively stimulated shoot initiation. The lowest shoot number was observed in the control treatment, reflecting limited endogenous hormonal activity.

Covering treatment (S1) increased the number of shoots across all PGR levels. The highest shoot production was recorded in cuttings treated with Rapid Root under covered conditions, suggesting that optimal humidity and reduced environmental stress enhanced the effectiveness of auxin-mediated shoot development. Covering likely reduced transpiration and maintained physiological stability, allowing assimilates to be allocated toward bud growth.

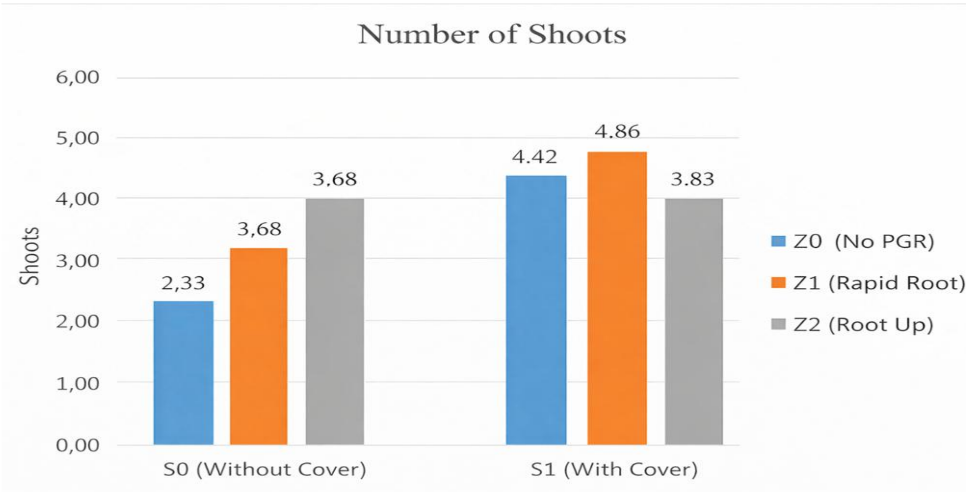

Fig. 3: Number of Shoots

The interaction between PGR and covering indicates that shoot proliferation is maximized when hormonal stimulation is combined with favorable microclimatic conditions. These results are consistent with the study of Alpandari *et al*., (2024) who reported increased shoot formation in vegetative propagation systems under controlled humidity and auxin application.

4.5. Fresh Weight of Shoots and Roots (g) - Dry Weight of Shoots and Roots (g)

The results showed that neither plant growth regulator (PGR) application nor covering treatment significantly affected fresh and dry weights of shoots and roots, as indicated by the same significance letter across treatments (Table 1). This suggests that variations in biomass accumulation among treatments were statistically similar under the experimental conditions.

Table 1: Fresh Weight of Shoots and Roots (g) - Dry Weight of Shoots and Roots (g)

Treatment	Shoot Fresh Weight (g)	Root Fresh Weight (g)	Shoot Dry Weight (g)	Root Dry Weight (g)
		PGR		
No PGR (Z0)	5.84a	0.69a	1.46a	0.60a
Rapid Root (Z1)	6.55a	1.03a	1.74a	0.57a
Root Up (Z2)	6.21a	0.81a	1.59a	0.46a
		Covering		
Without Cover (S0)	7.05a	0.94a	1.82a	0.66a
With Cover (S1)	5.35a	0.75a	1.38a	0.42a
Interaction(PGR × Covering)	(–)	(–)	(–)	(–)
		Treatment Combination		
Z0S0	4.99a	0.38a	1.22a	0.64a
Z1S0	9.56a	1.60a	2.54a	0.93a
Z2S0	6.59a	0.82a	1.69a	0.42a
Z0S1	6.68a	1.00a	1.70a	0.56a
Z1S1	3.53a	0.45a	0.95a	0.21a
Z2S1	5.82a	0.80a	1.50a	0.50a

Note: Values followed by the same letter in the same column are not significantly different at the 5% level.

Although not significantly different, Rapid Root (Z1) tended to produce higher fresh and dry shoot weights compared to other ZPT treatments, particularly under non-covered conditions (Z1S0). This trend indicates that auxin-based PGRs may enhance assimilate allocation toward shoot growth, although the effect was not strong enough to cause a significant difference. Similar tendencies were observed in root fresh weight, where Z1S0 showed the highest numerical value, reflecting improved root development under optimal aeration and light conditions.

Covering treatment (S1) generally resulted in lower fresh and dry biomass compared to non-covered treatment (S0). This may be attributed to reduced light intensity under covering, which can limit photosynthetic activity and subsequently decrease dry matter accumulation. While covering improved early growth parameters such as shoot emergence and survival, it appeared less favorable for biomass accumulation at later stages.

The absence of interaction effects between PGR and covering further indicates that these treatments independently influenced growth dynamics rather than synergistically affecting biomass production.

5. Conclusion

The final results showed that the treatment of zpt was significantly different in the percentage of growth, time of shoot emergence, shoot length at 8 WAP, and the number of shoots at 10 WAP. The treatment of covering significantly differed in the time of shoot emergence, shoot length at 8 WAP, and the number of shoots at the ages of 4, 8, and 10 WAP. There was an interaction between the provision of PGR and covering on the percentage of shoot growth, time of shoot emergence, number of roots, shoot length at 8 WAP, and number of shoots at 8 and 10 WAP.

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Conflict of Interest

The authors declare no conflict of interest.

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