

Root Formation Response of Oil Palm (*Elaeis guineensis* Jacq.) to Naphthaleneacetic acid (NAA) and Indole-3-butyric acid (IBA) under *In Vitro* Condition

Muhammad Ilham^{1*}, Ernayunita², and Hernawan Yuli Rahmadi³

¹²³Plant Breeding Research, Indonesian Oil Palm Research Institute (IOPRI), Medan, North Sumatera, Indonesia

*Corresponding author: ilhambawazier04@gmail.com.

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ABSTRACT

The root system of oil palm (*Elaeis guineensis* Jacq.) is a critical component for plant growth. Roots play essential roles in water and mineral absorption, providing structural support, storing energy, and facilitating interactions between plants and microorganisms. In tissue culture, root initiation is one of the key parameters for the successful formation of plantlets. This study aims to analyze the response of growth regulators in inducing roots and increasing the percentage of root formation in oil palm plantlets *in vitro* using 1-naphthaleneacetic acid (NAA) and indole-3-butyric acid (IBA). The methods included plant material preparation, root growth medium preparation, treatment media preparation, inoculation and incubation, and data analysis. The experimental design employed a Completely Randomized Design (CRD) with nine treatments and one control, each repeated seven times, resulting in 70 experimental units. The data were analyzed using ANOVA, followed by further testing with DMRT at a 5% significance level. The results showed that NAA and IBA positively influenced root formation in oil palm plantlets. A single NAA treatment effectively stimulated root elongation and reduced the time required for root emergence. The combination treatment of 1 mg/L NAA + 2 mg/L IBA produced a higher number of roots in the plantlets.

Keywords: IBA, NAA, Oil palm clone, Planlets, Root Induction.

INTRODUCTION

The root system of oil palm (*E. guineensis*) consists of four types of roots classified based on diameter size and growth rate: primary roots (Ø 5–10 mm), secondary roots (Ø 1–4 mm), tertiary roots (Ø 0.5–1.5 mm), and quaternary roots (Ø 0.2–0.5 mm). Additionally, oil palm roots are categorized into three types, with tertiary and

quaternary roots combined into a single category [1] (Corley & Tinker, 2016). Oil palm roots have the ability to grow and develop both vertically and horizontally. Root proliferation reflects the growth rate of roots in these two directions and is directly related to their capacity to absorb water and nutrients from the growing medium

The root quality of oil palm plantlets is crucial for their success during the acclimatization phase. Plantlets without roots can have negative effects during this stage, thus hindering the success of oil palm propagation through tissue culture techniques [2]. One alternative to enhance root development in oil palm is the use of plant growth regulators (PGRs). PGRs play significant roles in stimulating cell division, stem elongation, promoting root growth, assisting in cell differentiation, tissue differentiation, and increasing fruit set [3]. Auxins, a type of PGR, are commonly used in tissue culture techniques. Auxins play an essential role in the growth and development of plants, particularly in processes such as cell division, cell elongation and differentiation, as well as serving as signals between cells, tissues, and plant organs. The presence of auxins in the medium influences root initiation and growth. Two widely used auxins in plant tissue culture are Naphthalene acetic acid (NAA) and Indole-3-butyric acid (IBA). These synthetic auxins are frequently applied in plant multiplication [4] (Costa et al., 2017).

Root elongation in oil palm plantlets *in vitro*

using MS solid medium supplemented with 4 mg/L NAA and 4 mg/L IBA produced the best results. The average number of roots reached 2.9, with a length of 1.28 cm after 8 weeks of planting [5] (Yunita et al., 2016). Additionally, [6] Riyadi & Sumaryono (2010) reported that NAA had a stronger influence than IBA in root formation in oil palm plantlets. The use of NAA at concentrations ranging from 0.93–3.72 ppm resulted in root initiation percentages exceeding 40%. According to [7] the optimal concentration of NAA for inducing roots in oil palm shoots *in vitro* was 0.1 ppm.

It is important to carefully consider the concentration levels when using plant growth regulators (PGRs). The aims of this study is to analyze the response of plant growth regulators in inducing roots in oil palm plantlets. The composition of tissue culture media with the appropriate addition of PGRs is expected to increase the percentage of root formation in oil palm plantlets, supporting the production of clones.

MATERIALS AND METHODS

Preparation Plant Materials

The research was conducted from November 2023 to January 2024 at the Plant Tissue Culture Laboratory, Indonesian Oil Palm Research Institute (IOPRI), Medan, North Sumatra. The primary plant material used consisted of shoots

derived from oil palm clones cultivated *in vitro* under continuous light conditions (Fig 1). The environmental conditions during the study were controlled at a temperature of $25 \pm 2^{\circ}\text{C}$ to support optimal root growth.

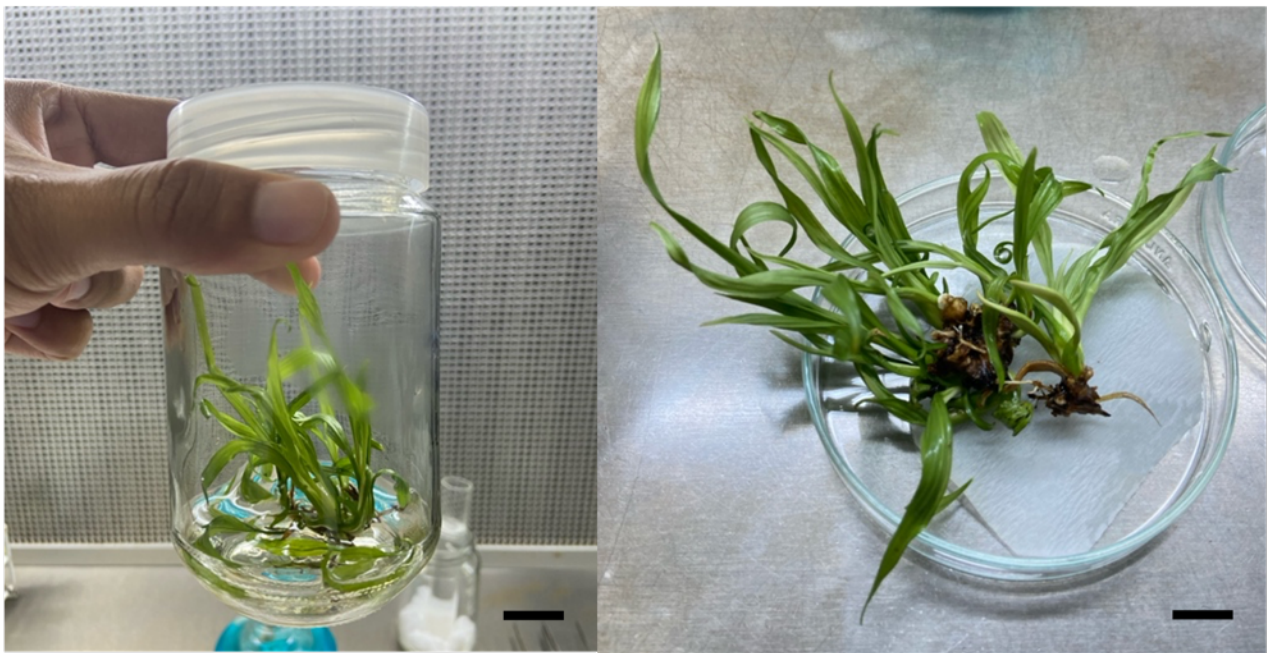


Fig 1. Shoots derived from oil palm (*E. guineensis*) clones. Scale bar = 5 cm.

Preparation of Rooting Medium for Oil Palm

The medium used in this study refers to Murashige and Skoog (1962), with the addition of plant growth regulators including Naphthalene

Acetic Acid (NAA) and Indole-3-Butyric Acid (IBA) at concentrations of 1 mg/L, 2 mg/L, and 3 mg/L NAA, respectively. The treatment combinations are outlined in Table 1.

Table 1. Plant Growth Regulator (PGR) Combination NAA + IBA

PGR		IBA (I)		
		1mg/L	2 mg/L	3 mg/L
NAA (N)	1 mg/L	N ₁ I ₁	N ₁ I ₂	N ₁ I ₃
	2 mg/L	N ₂ I ₁	N ₂ I ₂	N ₂ I ₃
	3 mg/L	N ₃ I ₁	N ₃ I ₂	N ₃ I ₃
(Control) (NAA single)				

Statistical analysis

The study used a Completely Randomized Design (CRD). The treatment design consisted of 9 treatment combinations and 1 control. Each treatment was repeated 7 times, resulting in a total of 70 experimental units. The parameters observed included plant height, number of leaves, number of

roots, root length, and root emergence. The data collected were analyzed using SPSS software (IBM, USA) through Analysis of Variance (ANOVA) at a 95% confidence level, followed by Duncan's Multiple Range Test (DMRT) with a significance level of $p < 0.05$

RESULTS AND DISCUSSION

Root Induction in Oil Palm (E. guineensis)

The results of the study showed that the oil palm planlets generally formed and developed roots in various treatment combinations at 4 weeks after planting (WAP). Root elongation, however, was observed to occur at 8 WAP. Based on the ANOVA analysis, it was found that the application

of plant growth regulators, NAA and IBA, to the oil palm planlets did not show significant differences in plant height and number of leaves. However, significant differences were observed in the number of roots, root emergence, and root length (Table 2).

Table 2. Morphological Characteristics of Oil Palm (*E. guineensis*) During 8 Weeks with the Addition of Plant Growth Regulators NAA and IBA

Treatments (mg.l ⁻¹)	Number of Leaves	Plant Height (cm)	Number of Roots	Roots Emergence	Root Length (cm)
Control	4.85 ± 1.06 ^a	9.71 ± 1.57 ^{abc}	1.75 ± 0.91 ^{ab}	1.07 ± 0.24 ^a	1.21 ± 0.64 ^a
N1I1	5.00 ± 1.00 ^a	9.78 ± 1.72 ^{abc}	1.95 ± 1.45 ^a	1.00 ± 0.27 ^{ab}	0.86 ± 0.19 ^b
N1I2	3.71 ± 0.48 ^{ab}	1.00 ± 1.7 ^{abc}	2.01 ± 1.30 ^a	1.00 ± 0.27 ^{ab}	0.75 ± 0.10 ^b
N1I3	3.57 ± 0.53 ^{ab}	9.03 ± 1.29 ^{bc}	1.09 ± 0.71 ^{ab}	0.85 ± 0.24 ^{abc}	0.75 ± 0.10 ^b
N2I1	3.85 ± 1.06 ^{ab}	9.78 ± 1.46 ^{abc}	0.71 ± 0.00 ^c	0.78 ± 0.19 ^{bc}	0.71 ± 0.00 ^b
N2I2	4.71 ± 2.87 ^{ab}	11.1 ± 1.17 ^a	1.00 ± 0.50 ^{ab}	0.92 ± 0.27 ^{abc}	0.71 ± 0.00 ^b
N2I3	3.14 ± 1.06 ^b	9.07 ± 1.96 ^{bc}	1.19 ± 0.95 ^{ab}	0.78 ± 0.19 ^{bc}	0.76 ± 0.13 ^b
N3I1	4.42 ± 0.97 ^{ab}	10.3 ± 1.44 ^{ab}	1.04 ± 0.89 ^{ab}	0.71 ± 0.00 ^c	0.78 ± 0.19 ^b
N3I2	3.57 ± 0.78 ^{ab}	8.38 ± 0.73 ^c	0.71 ± 0.00 ^c	0.78 ± 0.19 ^{bc}	0.71 ± 0.00 ^b
N3I3	4.57 ± 1.61 ^{ab}	9.41 ± 1.02 ^{abc}	0.71 ± 0.00 ^c	0.71 ± 0.00 ^c	0.71 ± 0.00 ^b

Note: Columns with the same letter are not significantly different based on the Duncan's Multiple Range Test (DMRT) at $p \leq 0.05$.

Based on Table 2, the highest number of roots was produced by the treatment of NAA 1 mg/L + IBA 2 mg/L, with an average of $2.01 \pm 1.30a$. This is consistent with the findings of [8], where the number of roots increased in the fourth week, with the number continuing to rise until the seventh week, with an average of about **3.26**. Meanwhile, a study by [9] reported that the addition of 5 mg/L NAA and GA₃ to the media for planlet maturation resulted in the formation of primary roots in the OG hybrid planlet. Additionally, the combination of NAA and IBA enhanced the percentage of root formation and the number of leaves in oil palm during root initiation. The highest root induction percentage was achieved with the combination of NAA 10 µM and IBA 20 µM, which reached 73.3% [6]

Furthermore, the root emergence time ($1.07 \pm 0.24a$) and root length ($1.21 \pm 0.64a$) in the control treatment (single NAA) showed the best response in accelerating root growth and root elongation. This is consistent with the study by [5] where the application of NAA single was considered more effective compared to the combination of NAA and IBA for root induction in oil palm *in vitro*. [10] mentioned that the application of 1 mg/L NAA single was able to initiate root elongation in *Phoenix dactylifera* L. planlets with an average of 3.65 ± 1.55 and a root emergence percentage of 87%, as NAA can stimulate root growth at low concentrations. Plant growth regulators (PGRs) such as IBA and NAA showed significant improvement in branch growth, number and length of roots, new leaf count, and percentage of dry matter in leaves when compared to the control treatment [11]. Root initiation in *Phoenix dactylifera* (Arecaceae) using 2 mg/L IBA showed a root count of 4.48 ± 0.19 and root length of 3.57 ± 0.19 [12]. The exogenous application of auxins influences the differentiation of oil palm roots. The use of exogenous auxins plays a crucial role in *in vitro* root formation. Without auxins, only 39.2% of the seedlings survived after 60 days [2]

***Growth of E. guineensis* Planlets in response to NAA and IBA**

The growth response of *E. guineensis* planlets depends on the application of plant growth regulators (PGRs). This study examines growth through several parameters, including the number of leaves, plant height, number of roots, root emergence, and root length, which were observed every two weeks until the eighth week (Fig 2). Based on Figure 2, the highest plant height of oil palm planlets (*E. guineensis*) was obtained from the N₂I₂ treatment (2 mg/L NAA + 2 mg/L IBA) at 8 weeks after planting (WAP), with a percentage increase of 11%. Both NAA and IBA contribute to growth and development, particularly in root elongation. The highest number of leaves was observed in the N₁I₁ treatment (1 mg/L NAA + 1 mg/L IBA) at 8 WAP, with an average of 5.00 leaves. The highest number of roots was also observed in the N₁I₁ treatment (1 mg/L NAA + 1 mg/L IBA) at 8 WAP, with an average of 2.38 roots. This is supported by [13], who showed that the use of the auxin hormone IBA could have a negative effect on explant growth, especially when applied in combination with NAA, due to the toxic effects on the planlets. It is also suspected that *E. guineensis* planlets have sufficient endogenous auxins for initiating root growth, so excessive exogenous auxin applications can hinder plant growth and development.

Meanwhile, in the parameters of root emergence and root length, NAA and IBA treatments did not have a significant effect on the root growth of *E. guineensis* plants. In this parameter, the control treatment (NAA single) was able to induce root growth and development. This finding is consistent with the study by [14], which explained that the use of MS medium supplemented with 0.25 ppm NAA for oil palm root induction resulted in an average root number of 2.4. Similarly, [15] reported that the application of 500 ppm NAA produced the highest root percentage (24.5%) in date palm plants. In the study conducted by [16], the application of 2.0 ppm NAA and 1.5 ppm BAP had a significant effect on

the germination of *Arenga pinnata* through tissue culture techniques. Root elongation was enhanced in MS medium containing 0.1 mg/L NAA and 0.1 mg/L BA. Additionally, the incorporation of 3 g/L activated charcoal and root pruning before the rooting stage in a specialized root medium proved essential for leaf and root elongation, as well as for promoting the formation of secondary and tertiary roots [17]. Furthermore, soaking the base of plantlets in FeSO₄ nanoparticles (NPs) at 0.5% + NAA 8% and ZnSO₄ nanoparticles (NPs) at 0.5% + NAA 8% was shown to stimulate root length, total root weight, the number and weight of small roots, the number and weight of large roots, and the success rate of plantlet establishment [18]. This study demonstrates that the application of plant growth regulators, specifically NAA and IBA, has a significant effect on the growth of *E. guineensis* plantlets.

Based on Figure 2, the growth response of *E. guineensis* plantlets from week 0 to week 8 to variations in plant growth regulators NAA and IBA shows favorable growth across all parameters observed every two weeks. Each treatment exhibited growth improvement, indicating that the treatments positively affected plant height and the overall number of leaves. For the parameters of the number of roots, root emergence, and root length, low concentrations effectively stimulated good root formation. In contrast, treatments with higher concentrations tended to inhibit root growth, likely due to the toxic effects caused by excessive PGR concentrations. The growth of each treatment is visualized in Figure 3. *E. guineensis* plantlets

showed a good response to the application of NAA single (Figure 3A) and the combination of 1 mg/L NAA + 1 mg/L IBA (Figure 3B).

The combination of NAA and IBA in the N₃I₃ treatment showed no root growth. This is suspected to be due to the application of excessively high exogenous auxin levels, which caused disturbances in the plantlet's metabolism. When high concentrations of auxin are present at the cellular level, the ubiquitination complex is activated in response to the auxin co-receptor protein (TIR), which leads to the degradation of the transcriptional repressor molecules (Aux/IAA), leaving the transcription factors free to transcribe genes in response to auxin, thus disrupting the cells. At low concentrations, auxin tends to suppress gene transcription through the interaction between the transcriptional repressor proteins (Aux/IAA) and the ARF transcription factor. Additionally, small endogenous non-coding RNAs, such as miRNAs or ncRNAs, play a role in auxin signaling pathways by regulating gene expression, both in immune responses to stress and in various other plant developmental processes. Therefore, auxin is considered a central control in plants due to its widespread role in various tissues, regulating essential biological processes that support growth, development, and adaptation to adverse environmental conditions ([19]; [20]; [21]; [22]).

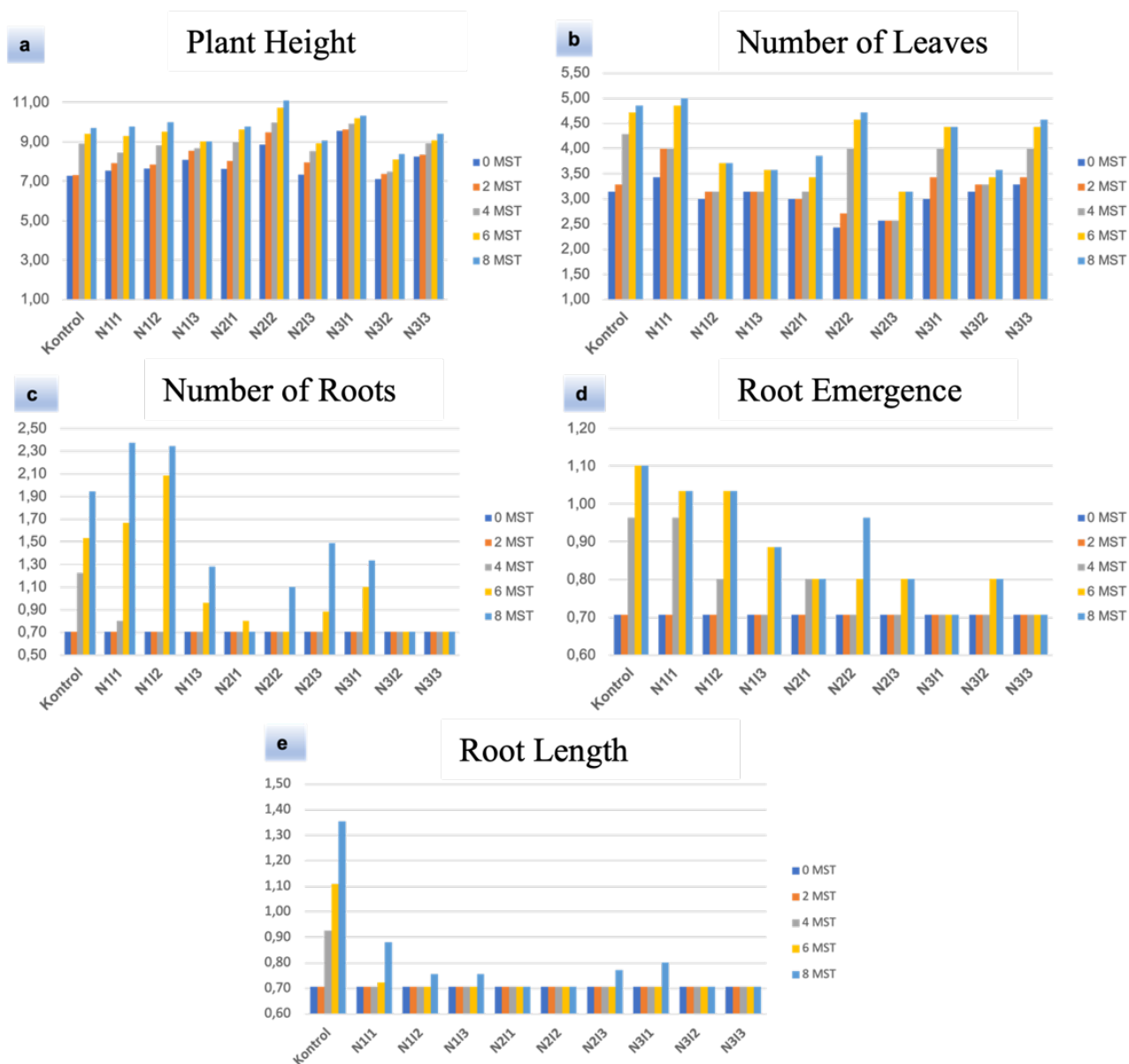


Fig 2. Growth Response of *E. guineensis* Planlets at 2 MST, 4 MST, 6 MST, and 8 MST to Variations in Plant Growth Regulators NAA and IBA. Note: a) Plant height, b) Number of leaves, c) Number of roots, d) Root emergence, and e) Root length.

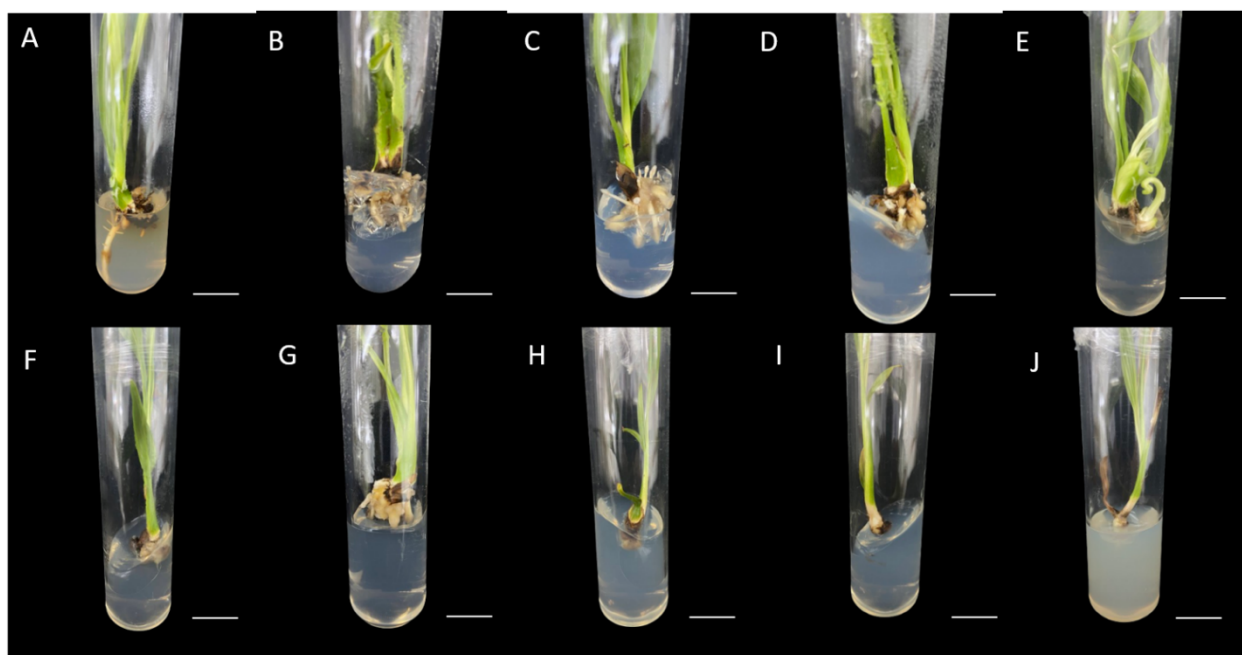


Fig 3. Morphology of *E. guineensis* (oil palm) root growth at 8 weeks for each treatments. Note: A (Control), B (N₁I₁), C (N₁I₂), D (N₁I₃), E (N₂I₁), F (N₂I₂), G (N₂I₃), H (N₃I₁), I (N₃I₂), J (N₃I₃). N₁ = 1 mg/L NAA, N₂ = 2 mg/L NAA, N₃ = 3 mg/L NAA; I₁ = 1 mg/L IBA, I₂ = 2 mg/L IBA, I₃ = 3 mg/L IBA. Bar = 5 mm.

Root induction using the PGRs NAA and IBA, when combined over 8 weeks (or 60 days), showed signs of root emergence, but root growth was not optimal. This is supported by [2], who stated that rooting begins after one month of culture, with the best root development occurring after three months, with maximum root growth observed on day 150. Therefore, a minimum of 90 days is required to achieve optimal root development. Factors related to the rooting phase, such as the presence of roots, root number, primary root length, and aerial part height, seem to influence the survival of seedlings during the acclimatization process. Although, in some plant species, the number and length of roots are directly linked to acclimatization success, no such relationship was found for oil palm, where in vitro root number and length did not correlate with seedling survival percentage during

acclimatization. Treatments that increased root induction percentages, rather than root number or length, were more effective in predicting plant survival [2]. Auxin IBA plays an important role in various aspects of root development, such as regulating the size of the root apical meristem, root hair growth, lateral root formation, and adventitious root development [23] [24]. Overall, this study demonstrates that applying PGRs at the right concentrations can enhance *E. guineensis* planlet growth, especially in terms of plant height and leaf number. However, attention must be paid to the dosages used, as excessive concentrations may lead to toxic effects that inhibit root formation. These findings provide valuable insights for the development of oil palm tissue culture and can serve as a basis for further research on optimizing PGR usage in oil palm, particularly in the production of clonal plants.

CONCLUSION

The addition of NAA and IBA can

influence the formation and development of roots

in *E. guineensis*. The NAA single was produced the best results for root emergence, with a value of 1.07 ± 0.24 and root length of 1.21 ± 0.64 cm. The

combination of 1 mg/L NAA + 2 mg/L IBA was effective in stimulating the number of roots in *E. guineensis*, reaching 2.01 ± 1.30 .

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