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ADVANCES IN SOCIAL HUMANITIES RESEARCH

Effectiveness of Giberellic Acid (GA3) Hormone and Biofertilizer (Bioneensis) on the Growth of Oil Palm Seedlings (Elaeis guineensis Jacq)

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Abstract

The nursery phase of oil palm (Elaeis guineensis Jacq.) cultivation represents a substantial cost in plantation establishment, and accelerating seedling growth may improve production efficiency. This study aimed to evaluate the effectiveness of gibberellic acid (GA_3) and Bioneensis biofertilizer in promoting the vegetative growth of oil palm seedlings in the main nursery. The experiment was conducted from March to June 2025 in Deli Serdang, North Sumatra, Indonesia, using six-month-old DxP PPKS 540 oil palm seedlings grown in polybags containing 20 kg of topsoil. A factorial randomized complete block design (RCBD) was employed with two factors: GA_3 concentrations (0, 100, 150, 200, and 250 ppm) and Bioneensis application rates (0, 25, 50, 75, and 100 g), applied at two-week intervals. The experiment consisted of 25 treatment combinations with two replications. Data were analyzed using analysis of variance (ANOVA) at a 5% significance level, followed by Duncan's multiple range test (DMRT). The results indicated that both treatments significantly affected plant height, stem diameter, leaf number, and leaf dry weight. The combination of GA_3 at 250 ppm and Bioneensis at 75 g (G250B75) produced the best overall vegetative growth, with 15 leaves, a stem diameter of 71.15 mm, a plant height of 120 cm, and the highest leaf dry weight of 227.5 g. However, the greatest plant height (144.5 cm) was observed under the G250B50 treatment. Bioneensis applied at 75 g was also associated with soil potassium and nitrogen concentrations of 21.52 ppm and 0.06%, respectively. These findings suggest that the combined application of GA_3 at 250 ppm and Bioneensis at 75 g may enhance the vegetative growth of oil palm seedlings and potentially reduce the nursery period from 12 to 9 months, although further validation is required to confirm this reduction.

INTRODUCTION

Various techniques for planting, fertilizing, and replanting oil palm have been developed to improve productivity while minimizing production costs. The adoption of cost-effective cultivation practices that comply with good agricultural practices has become increasingly important in oil palm plantation management. (Tabrani et al., 2016) reported that the application of gibberellic acid (GA_3) could increase oil palm growth by 20–50%, potentially

reducing maintenance costs and cultivation time. One important factor influencing the cost efficiency of oil palm replanting programs is the quality and production cost of planting materials. Generally, a 12-month-old oil palm seedling costs approximately IDR 40,000, with estimated monthly maintenance expenses of IDR 2,000 per seedling. If seedlings of comparable quality could be produced within nine months instead of 12 months, the nursery period could be shortened by three months, resulting in potential savings of IDR 6,000 per seedling while maintaining the same selling price (Andre Rigel et al., 2023; Ariyanti et al., 2023; Ramadhan et al., 2025; Sodikin et al., 2022).

Plant hormones occur naturally in higher plants, algae, and certain microorganisms, including fungi and bacteria, where they regulate various physiological processes associated with growth and development (Manurung et al., 2022). These naturally occurring compounds have attracted considerable attention in agricultural research because of their potential to improve crop productivity and cultivation efficiency. Among plant growth regulators, gibberellic acid (GA_3) plays an important role in stimulating cell elongation and promoting vegetative growth. Previous research demonstrated that GA_3 application increased oil palm seedling height by stimulating cellular elongation processes (Rudiansyah et al., 2017). Consequently, the application of GA_3 has been investigated as a potential strategy for accelerating seedling development and improving nursery management efficiency (Gusmawartati et al., 2025; Oktafianti et al., 2025; Putra et al., 2025).

The combined application of biofertilizers and GA_3 may further enhance the vegetative growth of oil palm seedlings by integrating hormonal regulation with improved soil nutrient availability. Biofertilizers contain beneficial microorganisms that contribute to nutrient cycling, biological nitrogen fixation, nutrient solubilization, and improved soil biological activity. Microbial genera commonly associated with plant growth promotion include Azospirillum spp., Azotobacter spp., Bacillus spp., and Pseudomonas spp., which may support root development and nutrient acquisition. In conventional oil palm cultivation, fertilizers are generally applied according to recommended rates; however, nutrient use efficiency may be reduced by losses through volatilization, leaching, erosion, and surface runoff. Therefore, integrating microbial biofertilizers into nursery management may provide an alternative approach to improving nutrient availability and reducing dependence on conventional fertilization practices (Chai et al., 2023; Pratiwi, 2026; Sukmawan & Riniarti, 2022).

Previous studies have demonstrated the potential of plant growth regulators, particularly GA_3, to enhance vegetative development through physiological processes such as cell elongation. Research has indicated that GA_3 application may increase oil palm seedling growth by approximately 20–50%, depending on treatment conditions and measured growth parameters (Tabrani et al., 2018). Similarly, biofertilizers containing beneficial microorganisms, including Azospirillum spp., Azotobacter spp., and Bacillus spp., have been investigated for their potential to improve soil biological activity, root development, and nutrient availability. These findings suggest that plant growth regulators and microbial biofertilizers may contribute to improved seedling performance through different but potentially complementary mechanisms.

Despite these findings, limited information is available regarding the combined application of GA_3 and specific biofertilizer formulations under oil palm main nursery conditions. Previous investigations have primarily examined the individual effects of plant growth regulators or microbial inoculants, while the potential interactions between these treatments remain insufficiently understood. In particular, the combined effects of different GA_3 concentrations and Bioneensis biofertilizer application rates on morphological growth characteristics and soil nutrient availability require further investigation. Addressing this research gap is essential to determine whether the simultaneous application of these treatments produces significant interaction effects and improves seedling growth compared with their individual applications.

The importance of this research lies in the increasing demand for efficient and sustainable oil palm nursery management practices. Commercial nurseries face challenges associated with prolonged seedling production periods, increasing maintenance costs, and the need to maintain high-quality planting materials. Identifying treatment combinations that accelerate vegetative growth without compromising seedling quality could contribute to improved nursery productivity and economic efficiency. In particular, producing nine-month-old seedlings with growth characteristics comparable to those of conventional 12-month-old seedlings could potentially reduce production costs and improve operational efficiency. However, achieving such a reduction would require evidence that accelerated vegetative growth is accompanied by adequate physiological development and seedling quality.

The novelty of this study lies in its systematic investigation of the combined effects of GA_3 and Bioneensis, a commercial microbial biofertilizer, on the vegetative growth of oil palm seedlings. Unlike studies that have evaluated plant growth regulators and biofertilizers separately, this research employed a factorial experimental design to examine their individual and interaction effects across multiple treatment levels. The investigation also incorporated measurements of soil chemical properties to assess changes in nutrient availability associated with the treatments. This approach was intended to provide a more comprehensive understanding of the relationship between exogenous GA_3 application, microbial biofertilization, and seedling growth responses under main nursery conditions.

The primary objective of this study was to evaluate the effectiveness of different GA_3 concentrations and Bioneensis biofertilizer application rates, both individually and in combination, in promoting the vegetative growth of oil palm seedlings in the main nursery. The investigation focused on morphological growth parameters, including plant height, stem diameter, leaf number, leaf area, and biomass accumulation, as well as changes in soil chemical properties. These measurements were used to assess treatment responses and identify combinations associated with improved seedling growth.

The findings of this study were expected to contribute to the development of more efficient oil palm nursery management practices by identifying suitable combinations of GA_3 and Bioneensis biofertilizer. Accelerating vegetative growth while maintaining seedling quality could potentially shorten the nursery period and reduce maintenance expenses. Based on an estimated monthly maintenance cost of IDR 2,000 per seedling, reducing the nursery period from 12 to nine months could generate potential savings of IDR 6,000 per seedling. Furthermore, improved nutrient availability through microbial biofertilizer application could

support more efficient nutrient management and contribute to sustainable oil palm cultivation. Nevertheless, these potential economic and agronomic benefits would require further validation under commercial nursery conditions.

Specifically, this study aimed to examine the individual and interaction effects of five GA_3 concentrations (0, 100, 150, 200, and 250 ppm) and five Bioneensis biofertilizer application rates (0, 25, 50, 75, and 100 g) on the vegetative growth and soil nutrient status of oil palm (Elaeis guineensis Jacq.) seedlings. The study sought to identify the treatment combination that produced the most favorable growth responses and changes in soil nutrient availability, thereby providing empirical evidence to support the development of improved nursery management recommendations.

METHOD

This study was conducted from March to June 2025 in Deli Serdang, North Sumatra, Indonesia, with laboratory analyses supported by the PPKS Medan Service Laboratory, PPKS Marihat Tissue Culture Laboratory, and University of North Sumatra Laboratory. Six-month-old DxP PPKS 540 oil palm seedlings were grown in polybags containing 20 kg of topsoil. The treatments consisted of five gibberellic acid (GA_3) concentrations (0, 100, 150, 200, and 250 ppm) and five Bioneensis biofertilizer application rates (0, 25, 50, 75, and 100 g), applied at two-week intervals. Standard nursery maintenance practices, including NPK (15-15-15) fertilization and pest and disease management, were implemented throughout the experiment. A factorial randomized complete block design (RCBD) was employed, comprising 25 treatment combinations with two replications. Data were analyzed using analysis of variance (ANOVA) at a 5% significance level, followed by Duncan's multiple range test (DMRT) when significant differences were detected.

The treatment combinations significantly affected plant height at weeks 12 and 14. At week 14, the greatest plant height for the GA_3 factor was recorded at G250 (123.6 cm), while the highest mean for the Bioneensis factor was 111.1 cm. Among the treatment combinations, G250B50 produced the tallest seedlings (144.5 cm). The greatest stem diameter was observed at G150 (68.35 mm) for GA_3, B25 (68.84 mm) for Bioneensis, and G200B25 (77.70 mm) for the combined treatments. The highest mean leaf numbers were recorded at G0 (14.6 leaves) for GA_3 and 15.2 leaves for Bioneensis, while G0B100 and G250B75 produced the highest values among treatment combinations (16.5 leaves). Leaf area did not differ significantly among treatments, although G250B0 produced the largest observed value (104.3 cm^2). Based on visual observations, G250B75 exhibited the most favorable overall seedling growth at nine months of age.

Biomass measurements at week 14 indicated no significant treatment effects on root volume or root length, although the highest values were observed under G250B75 (225 mL) and G150B75 (66.5 cm), respectively. Root fresh weight was significantly affected by Bioneensis application, with the highest mean recorded at B75 (213.5 g), whereas the greatest root dry weight was observed at B100 (57 g). Stem dry weight was significantly influenced by GA_3, with G0 differing significantly from G150, G200, and G250; a stem dry weight of 109.5 g was reported. Leaf dry weight was also significantly affected by GA_3, with G200 producing

197 g, and by Bioneensis, with B75 differing significantly from B50 and B0. Among the treatment combinations, G250B75 produced the highest leaf dry weight (227.5 g).

Environmental temperatures during the experiment ranged from 28.9 to 33.8°C, while relative humidity ranged from 52% to 66%. Laboratory analyses of plant tissues and growing media indicated changes in soil nutrient concentrations following Bioneensis application. The highest reported potassium concentration (21.52 ppm) and nitrogen content (0.06%) were observed at B75, while the highest reported C/N ratio value (2%) was recorded at B25.

RESULTS AND DISCUSSION

Based on the results of the study, the application of GA3 hormone has a significant effect on the vegetative growth of oil palm seedlings, as does the application of the bioneensis biofertilizer. The best combination of treatments based on the vegetative growth of the seedlings is the G250B75 treatment, namely the application of GA3 hormone at 250 ppm and biofertilizer at a dose of 75 grams. With the G250B75 treatment combination, the vegetative growth would result in 15 leaves and a stem diameter of 71.15 mm. Meanwhile, the plant height growth reaches 120 cm, while the highest growth is seen in the G250B50 treatment combination at 144.5 cm. In terms of seedling height growth, the G250B50 treatment combination has an average growth of 9.5 cm.

Table 2. Average Plant Height

G Factors									
G0		G100		G150		G200		G250	
98.9	c	105.3	bc	97.9	c	109.9	b	123.6	a
B Factors									
B0		B25		B50		B75		B100	
100.8	a	110.3	a	106.6	a	106.8	a	111.1	a
Combination of G and B									
	B0		B25		B50		B75		B100	
G0	90	i	101	efghi	90	i	108	defg	105.5	efgh
G100	104	efgh	109	def	97	fghi	102.5	efghi	114	cdef
G150	96	ghi	103.5	efgh	98.5	fghi	95.5	hi	96	ghi
G200	106	efgh	124	bc	103	efgh	108	defg	108.5	defg
G250	108	defg	114	cdef	144.5	a	120	bcd	131.5	b

Based on Ariyanti et al., (2018) research on seedlings in the 12th week, the increase in height of oil palm seedlings ranged from 8.96 to 9.56 cm. This height increase aligns with the study, where an increase in seedling height is not expected to exceed normal seedling growth. In (Alfred & Tony, 2024) study, seedlings grown at close spacing experienced etiolation, with plant heights reaching 105.92 cm in the third month.

In treatments using polybags, the third-month height, according to Alfred P's (2024) research, was 93.51 cm, and in the G150B75 treatment, the plant height was 95.5 cm. Seedling heights reaching 100 cm in the third month indicate the occurrence of etiolation, where cell

division and enlargement accelerate. In this case, seedlings that undergo etiolation are less suitable for transplantation to the main planting area.

Table 3. Average Stem Diameter

G Factors										
G0		G100		G150		G200		G250		
62.48	a	67.52	a	68.35	a	66.45	a	61.07	a	
B Factors										
B0		B25		B50		B75		B100		
63.68	a	68.84	a	62.07	a	67.09	a	64.19	a	
Combination of G and B										
	B0		B25		B50		B75		B100	
G0	60.55	a	66.7	a	54.75	a	62.05	a	68.35	a
G100	68.55	a	65.9	a	60	a	73.15	a	70	a
G150	70	a	69.35	a	65.4	a	67	a	70	a
G200	60.5	a	77.7	a	64.85	a	62.1	a	67.1	a
G250	58.8	a	64.55	a	65.35	a	71.15	a	45.5	a

Cell division triggered by the hormone gibberellin will cause differences in vegetative growth of G0 seedlings, namely seedlings without gibberellin hormone treatment. The factor of giving Bioneensis fertilizer also shows a significant difference. With the application of Bioneensis fertilizer, the main components in the cells present in the cytoplasm and vacuoles of the cells can more easily absorb water (Andra et al., 2023).

The application of Bioneensis fertilizer gives a significant difference in plant height starting from the 10th week, stem diameter in the 8th week, and the number of leaves in the 2nd week. According to (E. & Putra, 2025), the mechanism of root length enhancement can be associated with the role of microorganisms in dissolving essential nutrients required by plants. This also causes root elongation to be faster with the application of Bioneensis fertilizer. Seeds that are given bioneensis fertilizer will certainly increase the organic material content in the soil according to (Andika et al., 2024) soil that has a higher organic content can increase the soil's ability to retain water and air, thereby supporting the activity of soil microorganisms and accelerating the root breakout process.

Table 4. Average of Frond Number

G Factors										
G0		G100		G150		G200		G250		
14.6	a	14.3	a	15.1	a	14.1	a	14	a	
B Factors										
B0		B25		B50		B75		B100		
14.1	c	13.7	b	14.1	c	15	c	15.2	a	
Combination of G and B										
	B0		B25		B50		B75		B100	
G0	14	a	13.5	a	14.5	a	14.5	a	16.5	a

G100	14.5	a	14	a	14	a	15	a	14	a
G150	16	a	14.5	a	14	a	15	a	16	a
G200	14	a	13	a	14.5	a	14	a	15	a
G250	12	a	13.5	a	13.5	a	16.5	a	14.5	a

The number of oil palm leaves with the treatment factor of gibberellic acid hormone application and with the application of bioneensis biofertilizer once every two weeks to the plants during the 14-week observation period showed that gibberellic acid application had a significant effect in weeks 8, 12, and 10 weeks, while the application of bioneensis fertilizer had a significant effect only at weeks 2, 6, 8, and 14.

Biofertilizers have a working mechanism in increasing root length that can be linked to the role of microorganisms in solubilizing essential nutrients needed by plants. According to (Sriwahyuni & Parmila, 2019), microorganisms in biofertilizers can produce enzymes and secondary metabolite compounds that play a role in increasing the availability of nitrogen (N), phosphorus (P), and potassium (K) in the soil. (Asra, 2014) described that nitrogen is important for root tissue formation, phosphorus supports the development of deeper and stronger root systems, while potassium helps enhance root resistance to suboptimal environmental conditions.

Table 5. Average of Dry Weight of Leaves

Faktor G									
G0		G100		G150		G200		G250	
166.5	b	191.5	ab	182	ab	197	a	172	B
Faktor B									
B0		B25		B50		B75		B100	
160	c	190.5	ab	175	bc	203.5	a	180	abc
Kombinasi G dan B									
	B0		B25		B50		B75		B100	
G0	110	g	197.5	abcd	160	def	185	bccde	180	cdef
G100	197.5	abcd	202.5	abc	175	cdef	200	abc	182.5	cde
G150	167.5	def	190	abcde	200	abc	180	cdef	172.5	
G200	180	cdef	210	abc	187.5	abcde	225	ab	182.5	
G250	145	f	152.5	ef	152.5	ef	227.5	a	182.5	

In the observation of the leaf section, the dry weight of the leaves showed a significant difference in treatment factor G, where G0 had a significant effect on G200 with an average value of G200 of 197 g. For factor B, B75 showed a significant difference compared to treatments B50 and B0, while in the treatment combination, there was a significant difference in treatment G250B75, which had the highest average of 227.5 g.

With the increased availability of these nutrients, the roots of oil palm seedlings can grow longer and more efficiently absorb nutrients from the growing medium. In addition, environmental factors such as soil structure and organic matter content also greatly influence root growth. In observations of the leaf count parameter, the application of Bioneensis fertilizer

showed a significant difference in the treatment factor from the 2nd week, indicating the rapid role of microorganisms in the soil for cell division in leaf formation.

Table 6. Average Leaf Analysis for B0 Treatment

Sample	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
G0B0	2.57 b	0.185 b	1.01 c	0.59 a	0.28 a
G100B0	2.96 b	0.197 a	1.64 b	0.3 d	0.24 a
G150B0	2.78 b	0.173 c	1.77 a	0.28 b	0.2 d
G200B0	3.04 a	0.209 a	1.77 a	0.13 c	0.21 b
G250B0	3.21 a	0.174 c	1.78 a	0.15 c	0.17 c

Based on the results of data analysis obtained through observations conducted on leaves with treatment factor B0, namely without the use of bioneesis fertilizer. Based on Table 5, it is known that the highest nitrogen content is in sample G250B0, which is 3.21%, the highest phosphorus content is in sample G200B0, which is 0.209, and the highest potassium content is in treatment sample G250B0, which is 1.78. The highest calcium content was found in the G0B0 treatment at 0.59%, and the highest magnesium content was found in the 0.28% treatment.

Table 7. Soil Analysis Results Before and After Research

Sample	Ph (H2O)		Ph (KCL)		C (%)		N (%)		C/N		P (ppm)		K (ppm)	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
G0B0	4.5 (VA)	4.69 (A)	4 (VA)	4.09 (VA)	0.96 (VL)	1.52 (L)	0.14 (L)	0.19 (L)	7 (VH)	8 (VH)	10.55 (L)	163.36 (VL)	0.69 (VL)	16.43 (L)
G0B25	4.5 (VA)	6.18 (LA)	4 (VA)	5.61 (LA)	0.96 (VL)	1.43 (L)	0.14 (L)	0.16 (L)	7 (VH)	9 (VH)	10.55 (L)	132.7 (VL)	0.69 (VL)	17.41 (L)
G0B50	4.5 (VA)	6.46 (LA)	4 (VA)	6.07 (LA)	0.96 (VL)	1.6 (L)	0.14 (L)	0.19 (L)	7 (VH)	8 (VH)	10.55 (L)	133.25 (VL)	0.69 (VL)	21.46 (M)
G0B75	4.5 (VA)	6.91 (N)	4 (VA)	6.39 (LA)	0.96 (VL)	1.52 (L)	0.14 (L)	0.2 (L)	7 (VH)	8 (VH)	10.55 (L)	148.51 (VL)	0.69 (VL)	22.21 (M)
G0B100	4.5 (VA)	5.92	4 (VA)	5.37	0.96 (VL)	1.09 (L)	0.14 (L)	0.16 (L)	7 (VH)	7 (VH)	10.55 (L)	107.51	0.69 (VL)	20.37 (L)

(L A)	(L A)	(VL)

Based on the table, it is known that in the parameters before treatment, the pH value of H_2O was 4.5 and the pH value of KCl was 4. Meanwhile, the C content was 0.96%, the N content was 0.14%, the C/N ratio was 7%, the P value was 10.55 ppm, and the K value was 0.69 ppm. After 14 weeks of treatment, the analysis results show that the pH of H_2O increased most significantly with the B75 treatment, reaching 6.91, and the pH of KCl increased to 2.39. In terms of C, the highest increase was observed in the B50 treatment, reaching 0.56%.

The N content experienced the highest increase in the B75 treatment, which was 0.06%. In the C/N observation, the highest increase occurred in B25, which was 2%. P content experienced the highest increase in B0 and B75, which were 138 and 153, respectively. Finally, in the K content observation, the highest increase occurred in B75, which was 21.52 ppm. From the application of bioneensis fertilizer, it was found that there was an increase in soil content, especially K content.

CONCLUSION

The application of gibberellic acid (GA_3) and Bioneensis biofertilizer, both individually and in combination, significantly affected several vegetative growth parameters of oil palm (Elaeis guineensis Jacq.) seedlings in the main nursery. The G250B75 treatment combination (250 ppm GA_3 and 75 g Bioneensis) produced favorable overall growth, with 15 leaves, a stem diameter of 71.15 mm, and a plant height of 120 cm at 14 weeks after treatment. However, the greatest plant height (144.5 cm) was recorded under G250B50. The G250B75 treatment also produced the highest leaf dry weight (227.5 g) and exhibited the most favorable overall growth based on visual observations at nine months of age. Soil analysis indicated that Bioneensis application at 75 g was associated with the highest reported potassium concentration (21.52 ppm) and nitrogen content (0.06%), suggesting its potential to improve nutrient availability in the growing medium. These findings indicate that the combined application of GA_3 and Bioneensis, particularly at 250 ppm and 75 g, respectively, may enhance the vegetative growth of oil palm seedlings. However, further investigation is required to determine whether this treatment can consistently reduce the nursery period from 12 to nine months without compromising seedling quality.

Future research should validate these findings under different nursery and field conditions, using various oil palm genotypes and environmental settings to assess the consistency and applicability of the G250B75 treatment. Further investigations should examine the physiological and microbial mechanisms underlying the potential interactions between GA_3 and Bioneensis, particularly their roles in nutrient availability, nutrient uptake, and hormone-mediated cell elongation. Long-term studies should also evaluate whether accelerated nursery growth influences transplant establishment, subsequent vegetative development, and early yield performance under plantation conditions. Additionally, comprehensive economic assessments should compare the costs of GA_3 and biofertilizer applications with potential savings from a shorter nursery period. Further optimization of application rates, treatment

intervals, and biofertilizer formulations is recommended to establish practical and economically viable protocols for commercial oil palm nurseries.

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CONFLICT OF INTEREST

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AUTHOR CONTRIBUTION

All authors contributed to the preparation of this article. Author 1 Harzu contributed to the conceptualization of the study, data collection and analysis, interpretation of the results, and drafting of the manuscript, while the other authors contributed to reviewing, editing, and final approval of the manuscript..

GENERATIVE ARTIFICIAL INTELLIGENCE USAGE STATEMENT

The authors declare that they did not use generative artificial intelligence in the preparation of this article.

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