THE EFFECT OF COMPOST APPLICATION DOSAGE OF OIL PALM EMPTY FRUIT BUNCHES AND *Bacillus subtilis* ON THE GROWTH OF OIL PALM SEEDLINGS

Mira Ariyanti[1*], Lathif Rusmaputra[2], Intan Ratna Dewi Anjarsari[1], R Dwi Puspita Hendriawaty[2]
[1]Department of Agronomy, Faculty of Agriculture, Universitas Padjadjaran, Jl. Raya Bandung Sumedang km.21 Jatinangor Sumedang, West Java 45363, Indonesia
[2]Agrotechnology Study Program, Faculty of Agriculture, Universitas Padjadjaran, Jl. Raya Bandung Sumedang km.21 Jatinangor Sumedang, West Java 45363, Indonesia
*Correspondence: mira.ariyanti@unpad.ac.id

ABSTRACT

The continuous usage of chemical fertilizers for an extended period harms the environment. This can be minimized by using oil palm empty fruit bunch plantation waste (OPEFB) in organic fertilizer or compost enriched by *Bacillus subtilis* bacteria classified as Plant Growth Promoting Rhizobacteria (PGPR). Both OPEFB and *B. subtilis* can increase plant growth. This study aimed to determine the effect of OPEFB compost and *B. subtilis* with different doses on the growth of oil palm seedlings at nine months of age. This research was conducted at the Ciparanje Experimental Garden, Faculty of Agriculture, Universitas Padjadjaran, Jatinangor, from December 2022 until March 2023. This experiment used a randomized block design consisting of six treatments repeated four times. The treatments were: NPK fertilizer total 105 g/polybag; OPEFB compost 750 g/polybag; OPEFB compost 1000 g/polybag; *B. subtilis* bacteria 35 mL/polybag; OPEFB compost 500 g/polybag and *B. subtilis* 25 mL/polybag; OPEFB compost 500 g/polybag and *B. subtilis* 35 mL/polybag. The results showed that the application of OPEFB compost of 500 g/polybag and 35 mL/polybag *B. subtilis* affected the increase in oil palm seedling growth such as plant height by 11,25%, circumstance stems by 7,10%, number of leaves by 4,85%, and leaf area by 11,03%.

Keywords: *Bacillus subtilis*; oil palm; OPEFB compost; PGPR

Submitted : 30 September 2024
Accepted : 12 November 2024
Published : 15 November 2024

INTRODUCTION

Oil palm (*Elaeis guineensis* Jacq.) is one of the most widely traded food commodities in the ASEAN region, primarily due to its economic significance as an inexpensive source of oil (Herrera et al., 2019). This condition has encouraged many plantation farmers in Indonesia to cultivate oil palm, making it a promising industry prospect in both domestic and global markets (Widians & Farahdina, 2020). Increasing oil palm cultivation has increased the demand for fertilizers, pesticides, and seeds. The seedling process needs attention to produce quality seedlings by considering seed conditions, the environment, and the appropriate fertilizer dosage (Bariyanto et al., 2015).

Fertilization is one of the essential activities in oil palm cultivation, especially at the seedling stage. Currently, many still use chemical fertilizers continuously, which in the long term can cause environmental problems such as soil and water pollution, pest resistance, and threats to human health (Manguntungi et al., 2018).

Due to the high nutritional requirements and costs associated with chemical fertilizers for oil palm trees, there is a growing interest in more affordable alternatives that promote efficient nutrient use (Mia et al., 2010). Consequently, agricultural experts are exploring biofertilizers, which are economically viable options (Kumar et al., 2022). Biofertilizers are fertilizers that contain living microorganisms that enhance soil microbial activity. They serve as renewable, low-cost nutrient sources that can replace chemical fertilizers in an environmentally friendly way (Lima et al., 2018). These organic fertilizers are easy to produce and can be effectively applied in oil palm plantations. In a study by Pendey et al. (2000), inoculants of *B. subtilis* improved host plant survival by 88% and 100%, respectively, compared to control tea plants.

One alternative solution is utilizing plantation waste, such as empty fruit bunches (EFB) of oil palm, as organic fertilizer or compost, which is more environmentally friendly. Lignocellulosic residues from agricultural waste, mainly oil palm empty fruit bunch (OPEFB), serve as a promising feedstock generated as a by-product in palm oil production. Nevertheless, OPEFB is challenging to decompose because of its high lignocellulosic content, which consists of cellulose (35–45%), hemicellulose (25–40%), and lignin (15–25%) (Suksong et al., 2016). Furthermore, OPEFB is rich in organic materials, including carbon (480–490 kg/ton dry weight) and nitrogen (7.4–9.8 kg/ton dry weight), along with a high moisture content of 60% to 67% (Brunerová et al., 2018).

Using plantation waste such as OPEFB as organic fertilizer is considered environmentally friendly and rich in nutrients that plants need. Empty fruit bunches are dry solid waste from fresh fruit bunches (FFB) that can be used as organic fertilizer due to their nutrient content and ability to improve soil structure (Asra et al., 2015). Empty fruit bunches (EFB) waste production increases with expanding plantation areas and oil palm mills. This waste is often not utilized optimally and is merely burned, causing environmental pollution (Salmina, 2016). Therefore, alternative waste processing methods are needed, including turning it into compost (Hardinata et al., 2018).

Microbial products designed to enhance plant health and growth. Research has demonstrated that bacteria found in the plant rhizosphere positively influence both root health and plant development. These beneficial bacteria, known as plant growth-promoting rhizobacteria (PGPR), impact plant growth directly and indirectly, significantly contributing to their overall positive effects. One of the most straightforward approaches is utilizing substances that boost plant growth and alleviate stress (Singh & Pujari, 2022). One of the microbes that can be used is the bacterium *Bacillus* sp., which can solubilize phosphate and produce Indole Acetic Acid (IAA) hormones, making it commonly used as a biofertilizer and plant growth agent (Istiqomah et al., 2017). *Bacillus* sp. is known as a Plant Growth Promoting Rhizobacteria (PGPR) that plays a role in providing nutrients, producing phytohormones, improving soil structure, and enhancing plant resistance to pests and environmental stress (Hidayat et al., 2018).

The utilization of OPEFB waste as compost and the application of *B. subtilis* bacteria have the potential to enhance the growth of oil palm seedlings. This study aims to examine the effectiveness of the combination of OPEFB and *B. subtilis* in supporting the growth of oil palm seedlings in the main nursery to ensure that the seedlings planted in the field grow optimally.

MATERIALS AND METHODS

This research was conducted from December 2022 to March 2023 at the Ciparanje Experimental Garden, Faculty of Agriculture, Universitas Padjadjaran, located in Jatinangor, Sumedang, West Java, at an altitude of approximately 752 meters above sea level, with Inceptisol soil type. The tools for observation are hoes, scissors, shade nets, polybags, and measuring instruments. The materials used were OPEFB compost, NPK fertilizer, *B. subtilis* bacterial suspension, Inceptisol soil, water, and ±9-month-old oil palm seedlings of the DxP Simalungun variety. This study employed a Randomized Block Design (RBD) with six treatments and four replications and involved 48 oil palm seedlings. The treatments are as follows:

A = NPK fertilizer 105 g/polybag
B = OPEFB compost 750 g/polybag
C = OPEFB compost 1000 g/polybag
D = *B. subtilis* bacteria 35 mL/polybag
E = OPEFB compost 500 g/polybag + *B. subtilis* bacteria 25 mL/polybag
F = OPEFB compost 500 g/polybag + *B. subtilis* bacteria 35 mL/polybag

The experiment was carried out by preparing the planting media using soil from the Ciparanje Experimental Garden, which was sieved and mixed with OPEFB compost at different doses (500 g, 750 g, and 1000 g) and then placed in polybags. The oil palm seedlings were transferred into new polybags containing the soil and compost mixture, followed by watering. At the beginning of planting, *B. subtilis* suspension with a concentration of 10^{11} cfu/mL was applied at 25 mL/polybag and 35 mL/polybag around the seedlings. NPK fertilizer was applied every two weeks at 105 g/polybag for control plants over three months. Watering was conducted twice daily, even during rainy periods, as the experiment was conducted under a shade net. Weeds were removed every two weeks by hand and using hoes, and additional soil was added to the polybags if the seedlings were tilted. Pest and disease control was conducted by spraying Curacron 500 EC pesticide every two weeks.

Seedling growth measurements include several key parameters taken every two weeks from 0 MAT (months after treatment) to 12 MAT. Plant height was measured from the base of the stem to the tip of the highest leaf using a fabric measuring tape. The number of leaves was counted by tallying all fully opened leaves. Stem circumference was measured 5 cm above the base of the seedling, also with a fabric measuring tape. Leaf area was determined by recording the length and width of all fully opened leaves using a ruler or measuring tape. Additionally, the chlorophyll content of the leaves was assessed by sampling the largest and fully opened leaflets from the plant's top, middle, and bottom sections; the results averaged.

RESULTS AND DISCUSSION

Results

Final soil analysis showed that the application of OPEFB compost improved the content of total nitrogen (0,34%), available P_2O_5 (100.2 mg/kg), available K2O (7.2 mg/kg), potential P_2O_5 (150 mg/100g), and potential K_2O (77 mg/100g). The OPEFB compost used also contained nutrients such as nitrogen (2,45%), phosphorus (0,25%), and organic carbon (17,8%), which contributed additional nutrients to the soil. Based on the results, the total nitrogen (N-total) content increased by 0,27%, 0,34%, and 0,28% for the treatments with 500 g OPEFB compost + 35 mL *B. subtilis*, 1000 g OPEFB compost, and 35 mL *B. subtilis*, respectively.

Table 1 showed that all treatments, including inorganic fertilizers, OPEFB compost, and *B. subtilis*, positively affected the height of oil palm seedlings. The treatment with *B. subtilis* at 35 mL/polybag tended to provide better results than other treatments. The treatments of *B. subtilis* at 35 mL/polybag, OPEFB compost at 500 g/polybag combined with *B. subtilis* at 35 mL/polybag, and OPEFB compost at 750 g/polybag showed increases in seedling height of 14,19%, 11,25%, and 3,02%, respectively.

According to Table 2, all treatments had a similar effect on circumstance stems of oil palm seedlings. However, the treatment with *B. subtilis* at 35 mL per polybag resulted in an enormous stem girth compared to other treatments, with an average increase of 16,61% compared to the control treatment using NPK fertilizer (105 g/polybag). Table 2 also showed positive increases in circumstance stems for the treatments with 750 g OPEFB compost, 1000 g OPEFB compost, and 500 g OPEFB compost combined with 35 mL of *B. subtilis*, with increases of 7,89%, 5,75%, and 7,10%, respectively, compared to the NPK fertilizer treatment.

Table 3 showed that from 1 to 3 MAT, the application of *B. subtilis* at 35 mL per polybag resulted in a significant increase in the number of leaves, with a 30,16% improvement compared to the control treatment using NPK fertilizer (105 g/polybag). Combining 500 g OPEFB compost with 35 mL *B. subtilis* showed a 4,85% increase, and for the treatment with 1000 g OPEFB compost, which increased by 3,28%.

Table 1. Percentage Increase in Oil Palm Seedling Height Growth with OPEFB and *B. subtillis* Applications*

Treatments	Percentage increase in oil palm seedling height growth (%)			
	1 MAT	2 MAT	3 MAT	Average
A	-	-	-	-
B	3.37	3.08	2.61	3.02
C	1.84	0.42	-2.98	-0.24
D	16.52	15.24	10.81	14.19
E	-8.48	-7.46	-10.02	-8.65
F	13.14	12.07	8.53	11.25

Notes: * values compared with inorganic fertilizer treatment (treatment A)
A negative percentage increase (-) indicates that the average value of that treatment is lower than the inorganic fertilizer treatment.

Table 2. Percentage Increase in Oil Palm Seedling Circumstance Stems Growth with OPEFB and *B. subtillis* Applications*

Treatments	Percentage increase in oil palm seedling circumstance stems growth (%)			
	1 MAT	2 MAT	3 MAT	Average
A	-	-	-	-
B	11.65	6.77	5.26	7.89
C	9.72	3.76	3.76	5.75
D	22.49	21.69	5.64	16.61
E	-3.13	-6.77	-7.14	-5.68
F	9.64	5.26	6.39	7.10

Notes: * values compared with inorganic fertilizer treatment (treatment A)
A negative percentage increase (-) indicates that the average value of that treatment is lower than the inorganic fertilizer treatment.

Tabel 3. Percentage Increase in Oil Palm Seedling Number of Leaves with OPEFB and *B. subtillis* applications*

Treatments	Percentage increase in oil palm seedling number of leaves (%)			
	1 MAT	2 MAT	3 MAT	Average
A	-	-	-	-
B	-3.29	-5.97	-2.09	-3.78
C	7.24	2.09	0.52	3.28
D	32.89	42.93	14.66	30.16
E	-1.32	-1152	-17.28	-10.04
F	4.61	4.71	5.24	4.85

Notes: * values compared with inorganic fertilizer treatment (treatment A)
A negative percentage increase (-) indicates that the average value of that treatment is lower than the inorganic fertilizer treatment.

Table 4 showed that applying *B. subtilis* at 35 mL per polybag resulted in the highest leaf area compared to other treatments, with a 12,48% increase compared to the control treatment using NPK fertilizer (105 g/polybag). Additionally, there were positive increases in leaf area for the treatment combining 500 g OPEFB compost with 35 mL *B. subtilis,* which showed an 11,03% increase, and for the treatment with 1000 g OPEFB compost, which increased by 2,68%, compared to the NPK fertilizer treatment.

Discussion

Soil analysis showed that nitrogen and phosphorus are crucial for increasing the number of leaves, as they are essential in the composition of proteins and chlorophyll in leaves (Fauzi & Puspita, 2017). Organic carbon also serves as a food source for soil microorganisms, enhancing their activity in decomposition, phosphorus solubilization, and nitrogen fixation in the soil (Afandi et al., 2015).

Table 4. Percentage Increase in Oil Palm Leaf Area with OPEFB and *B. subtillis* applications*

Treatments	Percentage increase in oil palm leaf area (%)			
	1 MAT	2 MAT	3 MAT	Average
A	-	-	-	-
B	-5.18	-5.98	-1.80	-4.32
C	1.70	0.16	6.18	2.68
D	13.25	9.49	14.70	12.48
E	-17.05	-18.55	-15.96	-17.18
F	11.86	8.09	13.14	11.03

Notes: * values compared with inorganic fertilizer treatment (treatment A)
A negative percentage increase (-) indicates that the average value of that treatment is lower than the inorganic fertilizer treatment.

Increasing height is likely due to the application of OPEFB compost and *B. subtilis*, which support seedling growth through the nutrients N, P, K, and Mg contained in the OPEFB compost. Oil palm empty fruit bunch compost contains 2,45% total nitrogen (N), 0,25% phosphorus (P), 0,82% potassium (K), and 0,45% magnesium (Mg), with the added benefit of *B. subtilis* microbes that assist in meeting the plant's nutrient requirements. In addition, the C/N ratio of OPEFB is 14.9. This value is considered ideal as a nutrient provider for plants. This finding aligns with the statement by Amri et al. (2018), who noted that OPEFB compost application can fulfill the nutrient needs of plants.

Phosphorus, another essential macronutrient, is crucial for optimal plant development. It plays an essential role in critical metabolic processes, signal transduction, the production of macromolecules, and photosynthesis (Saeid et al., 2014). Plants struggle to absorb most of the available phosphorus because it is often found in insoluble, immobilized, or precipitated forms. Depending on their requirements, plants can absorb phosphorus as monobasic or dibasic phosphate ions. The rhizosphere soil is rich in phosphate-solubilizing bacteria (Wyciszkiewicz et al., 2015). These bacteria release low molecular weight organic acids, such as gluconic acid and citric acid, as well as phosphatase enzymes, which convert inorganic phosphorus into soluble monobasic or dibasic ions, making it easier for plants to absorb (Hayat et al., 2017).

The growth of oil palm seedlings is also influenced by internal factors such as plant genetics and external factors like environmental conditions, climate, and temperature. The research results show that the average height of the oil palm seedlings in this study was around 50,2 cm, likely affected by external factors such as climate, temperature, and surrounding environmental conditions. The seedlings were planted at approximately 752 meters above sea level (masl), with an average temperature of 22,8°C, leading to suboptimal growth. The altitude condition aligns with Darlan et al. (2017), who stated that oil palm grows optimally at 0-250 masl. However, it can generally be cultivated up to an altitude of 600 masl. The ideal temperature for oil palm growth is around 24-29°C (Nora & Mual, 2018).

The application of *B. subtilis* also positively affected the circumstance stems of oil palm seedlings. *B. subtilis*, acting as Plant Growth-Promoting Rhizobacteria (PGPR), can stimulate growth by producing auxin hormones, which plants utilize for their metabolic processes, including stem enlargement. *Bacillus subtilis* colonies can colonize the roots and promote lateral root growth due to the growth-promoting hormones secreted by the bacteria, thus enhancing nutrient absorption (Puspita et al., 2018).

The contribution of OPEFB compost, which provides macro and micronutrients such as N, P, K, and Mg, especially the K element, dramatically influences the enlargement of the stem girth of oil palm seedlings, resulting in an excellent seedling stem circumference. According to Waruwu et al. (2018), the role of the K element can accelerate the growth of meristematic tissues, particularly in the stem, strengthen the stem to prevent it from easily toppling over and play a crucial role in the photosynthesis process.

The application of both OPEFB compost and *Bacillus subtilis* had similar positive effects on stem girth, indicating that these treatments can be considered viable alternative fertilizers to support the growth of oil palm seedlings. Combining compost and beneficial microbes improves nutrient availability and enhances plant growth and development, making them promising options for sustainable oil palm cultivation.

This improvement is attributed to the role of *Bacillus subtilis* as a growth-promoting bacteria that produces growth hormones such as auxins and cytokinins and can solubilize phosphorus, making it available for plant use. According to Murtadho et al. (2016), Plant Growth-Promoting Rhizobacteria (PGPR) can produce growth hormones like auxins that stimulate branch formation and cell division, resulting in more active cell proliferation and increased formation of branches and leaves. The application of PGPR during composting is considered highly effective, as it boosts the production of various enzymes, leading to a quicker rate of waste decomposition. This process transforms waste into a humus-like material that can improve the soil's physical, chemical, and biological properties (Zahari et al., 2023).

The increased growth and number of leaves in oil palm seedlings are also attributed to the nutrients provided by OPEFB compost, which the plants absorb. According to Bariyanto et al. (2015), nutrients provided by OPEFB are utilized to form new cells, enhance cell division, and increase plant tissue, including the number of leaf stalks.

Increasing total nitrogen in the soil indicates that the application of OPEFB compost and *Bacillus subtilis* enriches the soil with nitrogen, contributing to the increased leaf area of oil palm seedlings. The leaf area is crucial for photosynthesis and is associated with chlorophyll content, which supports vegetative growth.

According to Santrum et al. (2021), a larger leaf surface area correlates with higher chlorophyll content, which enhances the rate of photosynthesis and accelerates plant growth. The observed positive increase is likely due to the combined effects of nutrient availability and growth hormones from applying OPEFB compost and *Bacillus subtilis.*

Bacillus subtilis produces growth hormones such as auxins that stimulate plant growth, particularly in root elongation. The length and surface area of the roots affect nutrient absorption; a more extensive and extended root system improves nutrient uptake. When the nutrient needs are met, photosynthesis becomes more efficient, ultimately influencing leaf area (Asra et al., 2015). Tinendung et al. (2014) also note that *Bacillus* species enhance root zone growth, stimulate vegetative growth phases, and increase photosynthetic activity.

CONCLUSION

The results showed that the application of oil palm empty fruit bunch (OPEFB) compost of 500 g/polybag and 35 mL/polybag *Bacillus subtilis* resulted in a percentage increase in oil palm seedling parameter such as plant height by 11,25%, circumstance stems by 7,10%, number of leaves by 4,85%, and leaf area by 11,03%.

REFERENCES

Adinurani, P. G., Rahayu, S., Zahroh, N. F. (2020). Aplikasi *Bacillus subtilis* pada beberapa bahan organik terhadap pertumbuhan dan produksi tanaman cabai rawit (*Capsicum frutescens* L.). *AGRI-TEK: Jurnal Ilmu Pertanian, Kehutanan, dan Agroteknologi*, *21*(1), 14–19.

Afandi, F. N., Siswanto, B., & Nuraini, Y. (2015). Pengaruh pemberian berbagai jenis bahan organik terhadap sifat kimia tanah pada pertumbuhan dan produksi tanaman ubi jalar di entisol Ngrangkah Pawon, Kediri. *Jurnal Tanah dan Sumberdaya Laha*n, *2*(2), 237-244.

Amri, A. I., Armaini, & Purba, M. R. A. (2018). Aplikasi kompos tandan kosong kelapa sawit dan dolomit pada medium subsoil inceptisol terhadap bibit kelapa sawit (*Elaeis guineensis* Jacq.) di pembibitan utama. *Jurnal Agroteknologi, 8*(2), 1-8.

Asra, G., Simanungkalit, T., & Rahmawati, N. (2015). Respons pemberian kompos tandan kosong kelapa sawit dan zeolit terhadap pertumbuhan bibit kelapa sawit di *pre nursery*. *Jurnal Online Agroekoteknologi*, *3*(1), 416–426.

Bariyanto, Nelvia, & Wardati. (2015). Pengaruh pemberian kompos tandan kosong kelapa sawit (TKKS) pada pertumbuhan bibit kelapa sawit (*Elaeis guineensis* Jacq.) di *main-nursery* pada medium subsoil Ultisol. *Jurnal Online Mahasiswa Faperta*, *2*(1).

Brunerova, A., Muller, M., Sleger, V., & Ambarita, H. (2018). Bio-pellet fuel from oil palm empty fruit bunches (EFB): using European standards for quality testing. *Sustainability*, *10*(12), 4443

Darlan, N. H., Listia, E., Pradiko, I., & Sucipto, T. (2017). Karakteristik tanaman kelapa sawit di dataran tinggi. *Warta Pusat Penelitian Kelapa Sawit, 22*(3), 122-129.

Fauzi, Y., Widyastuti, Y. E., Satyawibawa, I., & Paeru, R. H. (2012). *Kelapa Sawit*. Depok: Penebar Swadaya.

Hayat, W. Aman, H. Irshad, U., Azeem, M., Iqbal, A., & Nazir, R. (2017). Analysis of ecological attributes of bacterial phosphorus solubilizers native to pine forests of Lower Himalaya. *Applied Soil Ecology*, *112*, 51-59.

Hardinata, U., Kristalisasi, E. N., & Setyorini, T. (2018). Pengaruh pemberian kompos tandan kosong kelapa sawit dan volume penyiraman terhadap pertumbuhan bibit kelapa sawit di *pre nursery*. *Jurnal Agromast, 3*(1).

Hidayat, F., Rahutomo, S., Farrasati, R., Pradiko, I., Syarovy, M., Sutarta, E. S., & Widayati, W. E. (2018). Pemanfaatan bakteri endofit untuk meningkatkan keragaan bibit kelapa sawit (*Elaeis guineensis* Jacq.). *Jurnal Penelitian Kelapa Sawit*, *26*(2), 71–78.

Herera, M.N.Q., Guzman, R.S.C., Depositario, D.P.T., Mojica, L.E., & Madamba, J.A.B. (2019). Comparative palm oil trade performance in Indonesia, Malaysia, and the Philippines. *Journal of Global Bussines and Trade*, *15*(2), 51-78.

Istiqomah, Aini, L. Q., & Abadi, A. L. (2017). Kemampuan *Bacillus subtilis* dan *Pseudomonas fluorescens* dalam melarutkan fosfat dan memproduksi hormon IAA (*Indole Acetic Acid*) untuk meningkatkan pertumbuhan tanaman tomat. *Jurnal Buana Sain*, *17*(1), 75–84.

Kumar, S., Sindhu, S.S., & Kumar, R. (2022). Biofertilizers: An ecofriendly technology for nutrient recycling and environmental sustainability. *Microb. Sci, 3*, 100094.

Lima, F.A., Viana, T.V.A., de Sousa, G.G., Correia, L.F.M., & de Azevedo, B.M. (2018). Yield of strawberry crops under different irrigation levels and biofertilizer doses. *Rev. Cienc. Agron*, *49*, 381–388.

Manguntungi, B., Ardinata, R. A., Al Azhar, M., Asmawati, Putra, K. E., & Aprilian, T. (2018). Endonesia (*endophyte for Indonesia*): biofertilizer berbasis mikroba endofit guna meningkatkan kualitas pembibitan budidaya kelapa sawit (*Elaeis guineensis*) di Indonesia. *Jurnal Biota, 3*(1), 44–52.

Mia, M.A.B., & Shamsuddin, Z.H. (2010). *Rhizobium* as a crop enhancer and biofertilizer for increased cereal production. *Biotechnol, 9*, 6001–6009.

Nora, S., & Mual, C. D. (2018). *Budidaya Tanaman Kelapa Sawit*. Jakarta Selatan: Kementrian Pertanian.

Pandey, A., Palni, L.M.S., & Bag, N. (2000). Biological hardening of tissue culture raised tea plants through rhizosphere bacteria. *Biotechnol, 2*, 1087–1091

Puspita, F., Ali, M., & Pratama, R. (2017). Isolasi dan karakterisasi morfologi dan fisiologi bakteri *Bacillus* sp. endofitik dari tanaman kelapa sawit (*Elaeis guineensis* Jacq.). *Jurnal Agroteknologi Tropika*, *6*(2), 44–49.

Puspita, F., Saputra, S. I., & Merini, D. J. (2018). Uji beberapa konsentrasi bakteri *Bacillus* sp. endofit untuk meningkatkan pertumbuhan bibit kakao (*Theobroma cacao* L.). *Jurnal Agronomi Indonesia*, *46*(3), 322–327.

Saeid, A., Labuda, M. Chojnacka, K., & Górecki, H. (2014). Valorization of bones to liquid phosphorus fertilizer by microbial solubilization. *Waste and Biomass Valorization*, *5*(2), 265-272.

Salmina. (2016). Studi pemanfaatan limbah tandan kosong kelapa sawit oleh masyarakat di Jorong Koto Sawah Nagari Ujung Gading Kecamatan Lembah Melintang. *Jurnal Spasial*, *3*(2), 33–40.

Santrum, M. J., Tokan, M. K., & Imakulata, M. M. (2021). Estimasi indeks luas daun dan fotosintesis bersih kanopi hutan mangrove di Pantai Salupu Kecamatan Kupang Barat Kabupaten Kupang. *Haumeni Journal of Education, 1*(2), 38-43.

Sastrosayono, S. (2003). *Budidaya Kelapa Sawit*. Jakarta Selatan: AgroMedia.

Schmidt, F. H. & Ferguson, J. H. A. (1951). *Rainfall Types Based on Wet and Dry Period Ratios for Indonesia with Western New Guinea*. Jakarta: Kementerian Perhubungan Jawatan Meteorologi dan Geofisika.

Singh, G., & Pujari, M. (2022). *Bacillus subtilis* as a plant growth-promoting rhizobacteria: a review. *Plant Archives, 22*(2), 100-109.

Suksong, W., Kongjan, P., Prasertsan, P., Imai, T., & O-Thong, S. (2016). Optimization and microbial community analysis for production of biogas from solid waste residues of palm oil mill industry by solid-state anaerobic digestion. *Bioresource Technology (ELSEVIER), 214*, 166-174.

Tinendung, R., Puspita, F., & Yoseva, S. (2014). Uji formulasi *Bacillus* sp. sebagai pemacu pertumbuhan tanaman padi sawah (*Oryza sativa* L.). *Jurnal Online Mahasiswa Faperta, 1*(2).

Waruwu, F., Simanihuruk, B. W., Prasetyo, & Hermansyah. (2018). Pertumbuhan bibit kelapa sawit di *pre-nursery* dengan komposisi media tanam dan konsentrasi pupuk cair *Azolla pinnata* berbeda. *Jurnal Ilmu-Ilmu Pertanian Indonesia*, *20*(1), 7-12.

Widians, J. A. & Rizkyani, F. N. (2020). Identifikasi hama kelapa sawit menggunakan metode *certainty factor*. *Jurnal Ilmiah Ilkom*, *12*(1), 58–63.

Wyciszkiewicz, M. Saeid, A. Chojnacka, K. & Górecki, H. (2015). Production of phosphate biofertilizers from bones by phosphate-solubilizing bacteria Bacillus megaterium. *Open Chemistry*, *13*(1).

Yuliyanto, Sari, V. I., & Safrizal, R. (2017). Pemanfaatan kotoran manusia dan arang serbuk gergaji sebagai media tanam bibit kelapa sawit (*Elaeis guineensis* Jacq.) di pembibitan awal. *Jurnal Citra Widya Edukasi*, *9*(2), 199-210.

Zahari, N.Z., Tuah, P.M., Zulkifli, N., & Cleophas, FN (2023). Composting of oil palm empty fruit bunches by microbial inoculant. *International Journal of Technology*, *14*(5), 1081-1092.