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Growth Promotion of Oil Palm Seedlings (*Elaeis guineensis* Jacq.) with Slow-Release Fertilizer Application

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Abstract

Oil palm (*Elaeis guineensis* Jacq.) is a major source of vegetable oil and an important plantation commodity in the Indonesian economy. This study aims to determine the effect of slow-release fertilizer on the growth of oil palm seedlings in the primary nursery and to determine the nutrient status through laboratory analysis and spectroradiometer. The study was conducted at the IPB experimental station in Cikabayan, Dramaga, Bogor. Analysis of soil and leaf samples at the AGH Test Laboratory of the IPB University Department from December 2023 to July 2024. This study used a complete randomized block design with one factor, a nine-level fertilizer dose, and was repeated four times. Each experimental unit has 10 plants, so the total plant population is 360. Slow-release fertilizer can supply nutrients for a period of weeks. This study tested if it would benefit the growth of oil palm seedlings in the primary nursery. A slow-release fertilizer dose of 75% provides the best increase in oil palm seedling growth, whereas, at 50 and 150% doses, it did not increase compared to the control. The agronomic effectiveness value is above 95%.

Keywords: efficiency, leaf nutrient analysis, nutrient content, plant morphology,

Introduction

Indonesia is the world's largest crude palm oil (CPO) producer, with oil palm plantations covering 15.38 million hectares in 2022. These plantations comprise 6.37 million hectares of smallholder farms, 598.78 thousand hectares of state-owned plantations, and 8.4 million hectares of private estates. The country's total CPO production reached 48.23 million tons per year, with smallholder plantations contributing 15.49 million tons, state plantations 2.31 million tons, and private plantations 27.93 million tons. The average CPO yield is approximately 3.9 tons per hectare (Ministry of Agriculture, 2022). However, oil palm productivity is influenced by several factors, including land quality, genetic potential, and seed quality (Ministry of Agriculture, 2022).

Using high-quality, certified planting materials is critical to plantation success. Oil palm seeds must originate from certified superior varieties to ensure optimal growth and yield potential. Since the nursery phase is a preliminary stage requiring one year of preparation before field planting, proper nursery management is essential (Ariyanti et al., 2017).

Oil palm nurseries consist of two phases: the pre-nursery phase (three months) and the main nursery phase (nine months) (Sulardi, 2022). Effective nursery management is essential for maximizing genetic potential, as inadequate growth conditions can limit plant development (Mangoensoekarjo, 2013). Proper seedling care, including optimal fertilization, is necessary to achieve vigorous growth (Santi and Goenadi, 2016).

Plant productivity is fundamental for sustainable palm oil cultivation (Ibragimov et al., 2019). Nutrient availability significantly influences oil palm growth (Kamal and Manan, 2020). Nutrient deficiencies during the nursery stage can severely impact seedling development. For instance, nitrogen (N) deficiency in 9-month-old seedlings has been shown to reduce plant height by up to 12% (Sudradjat et al., 2014), while imbalances in calcium (Ca) and magnesium (Mg) can decrease stem diameter by 14% (Ningsih et al., 2015). Since soils often fail to supply adequate nutrients for optimal productivity, fertilization is

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necessary to maintain soil fertility and support plant growth (Khalida and Lontoh, 2019).

Fertilization strategies should minimize nutrient losses caused by leaching, volatilization, and erosion (Farrasati et al., 2021). Conventional fertilizers often result in nutrient inefficiency, leading to rapid depletion and potential environmental pollution. Slow-release fertilizers (SRFs) provide a controlled nutrient supply by gradually dissolving in soil moisture, reducing nutrient loss, and improving absorption efficiency (Cole et al., 2016). SRFs ensure prolonged nutrient availability, aligning nutrient release with plant demand, thus enhancing growth and productivity (Liu et al., 2021).

Previous studies have demonstrated that solid-compound SRFs significantly improve seedling growth and increase fresh fruit bunch (FFB) production in young oil palm plants (Wigena et al., 2006). Moreover, SRFs mitigate nutrient losses due to volatilization and leaching, reducing fertilizer application frequency and promoting sustainable nutrient management.

Given the advantages of slow-release fertilizers, further research is required to evaluate their efficacy in oil palm seedling development. This study aims to compare the growth performance of oil palm seedlings in primary nurseries using slow-release and conventional fertilizers. The findings will contribute to optimizing nursery fertilization practices, improving seedling vigor, and enhancing long-term plantation productivity.

Materials and Methods

This research was conducted at the IPB experimental field in Cikabayan, located at an altitude of 250 m above sea level in Dramaga, Bogor. The study period spanned from November 2023 to August 2024. The equipment used included a SPAD 502, digital scales, and ovens. The materials consisted of four-month-old D x P oil palm seeds of the “Sriwijaya-5” variety, 45 cm × 45 cm polybags, topsoil, and slow-release fertilizers NK 24-26.1, NPKMg 15-15-6-4, NPKMg 12-12-17-2, SP 36, along with kieserite, fungicides, and insecticides.

This study utilized a completely randomized block design with one factor: fertilizer dose. Nine levels of fertilizer dose, each repeated four times, resulted in 36 experimental units. Each experimental unit comprised ten plants, leading to a total plant population of 360. The treatment dosages are detailed in Table 1.

The nursery land was prepared in a 20 m x 20 m area, arranged in polybags spaced 90 cm × 90 cm × 90 cm apart. The initial phase of this activity involved using composite soil samples for analysis. Topsoil was the medium previously sifted to separate the other materials from the soil. The fertilizer dosages were administered as follows: the standard fertilizer at 50% and 100%, and test fertilizer at 25%, 50%, 75%, 100%, 125%, and 150%. Standard fertilizer refers to the recommended fertilization dosage for the oil palm nursery as per PPKS (PPKS, 2014), and the fertilizer dosage for each treatment was divided into 18 applications at two-week intervals (see Table 1). Fertilization was performed by burying the fertilizers around the plants in the polybags. Plant care involved spraying fungicides and insecticides weekly. Weed control in the polybags was conducted manually.

Morphological measurements of seedling height (cm), stem diameter (cm), and number of fronds were carried out every month until the end of planting, 10 months after planting. Observations of frond length

Table 1. Dosages of standard and slow-release fertilizer for oil palm seedlings

Treatments	Slow-release fertilizer (g per plant)	Standard fertilizer (g per plant)			
	NK 24-26.1	NPKMg 15-15-6-4	NPKMg 12-12-17-2	SP-36	Kieserite
Control (without fertilizer)	0	0	0	0	0
Standard fertilizer 50%	0	12.50	115.00	0	27.50
Standard fertilizer 100%	0	25.00	230.00	0	55.00
Slow-release fertilizer 25%	40.00	0	0	87.08	77.40
Slow-release fertilizer 50%	80.00	0	0	87.08	77.40
Slow-release fertilizer 75%	120.00	0	0	87.08	77.40
Slow-release fertilizer 100%	160.00	0	0	87.08	77.40
Slow-release fertilizer 125%	200.00	0	0	87.08	77.40
Slow-release fertilizer 150%	240.00	0	0	87.08	77.40

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(cm), leaf stalk width (cm), leaf length (cm), and plant dry weight (g) were performed at the end of planting 10 months after planting. Physiological observation of leaf greenness level was measured using a SPAD-502 Plus (Minolta) chlorophyll meter. One leaf from each sample, i.e., the 5th leaf from each treatment, was measured, totaling 36 plants. Leaf greenness level, N, P, K, Mg leaf content, was measured at the end of the planting period or 10 months after planting. The leaves were air-dried and then dried in an oven at a temperature of 60°C until a constant weight was reached before analysis.

The quantitative data was analyzed using the SPSS Statistics 25 program through the ANOVA variance test at a significant level of 5%; if there are significant differences, it will be further tested with the Duncan Multiple Range Test.

Results and Discussion

Seedling Height and Stem Diameter

The fertilizer dose treatment significantly affected the height of seedlings at 8, 9, and 10 months after planting. The 75% fertilizer dose treatment increased the height of oil palm seedlings by 10.06% at 8, 19.38% at 9, and 30.25% at 10 months after planting compared to the control (Table 2). In contrast, fertilizer treatments did not affect oil palm seedling stem diameter at 8, 9, and 10 months after planting (Table 2). However, the 75% fertilizer dose treatment increased the stem diameter by 34.38%, 18.49%, and 23.14% at 8, 9, and 10 months after planting, respectively, compared to the control (Table 2). The larger stem diameter was likely due to the optimal availability of N nutrients (Adileksana et al.,

Table 2. Oil palm seedling heights and stem diameter at 8, 9, and 10 months after planting

Treatments	8 months		9 months		10 months	
	Seedling heights (cm)	Stem diameter (cm)	Seedling heights (cm)	Stem diameter (cm)	Seedling heights (cm)	Stem diameter (cm)
Control (without fertilizer)	52.36abc	2.50	56.51d	3.04	66.95b	3.52
Standard fertilizer 50%	47.93bc	2.75	58.11bcd	3.20	81.54ab	3.67
Standard fertilizer 100%	55.74ab	2.81	65.47abc	3.48	84.20a	3.83
Slow-release fertilizer 25%	47.15c	2.74	59.21bcd	3.26	82.71ab	3.68
Slow-release fertilizer 50%	53.07abc	3.34	63.35abcd	3.46	90.22a	3.92
Slow-release fertilizer 75%	58.22a	3.81	70.10a	3.73	95.99a	4.58
Slow-release fertilizer 100%	55.19abc	2.90	67.45ab	3.59	90.91a	4.06
Slow-release fertilizer 125%	48.85bc	3.41	61.93abcd	3.39	82.96ab	4.01
Slow-release fertilizer 150%	54.23abc	2.99	64.89abcd	3.69	90.37a	4.14

Notes: Values followed by the same letter in the same column indicate no significant differences based on the DMRT at α=0.05.

Table 3. Oil palm number of fronds at 8, 9, and 10 months after planting

Treatments	Fronds number		
	8 months	9 months	10 months
Control (without fertilizer)	0.80b	2.84	2.84c
Standard fertilizer 50%	0.76b	3.37	3.37c
Standard fertilizer 100%	1.80a	4.16	6.07b
Slow-release fertilizer 25%	0.82b	3.44	4.34c
Slow-release fertilizer 50%	1.95a	4.17	6.75ab
Slow-release fertilizer 75%	2.17a	4.95	8.05a
Slow-release fertilizer 100%	2.02a	4.76	6.12b
Slow-release fertilizer 125%	1.3ab	3.86	6.11b
Slow-release fertilizer 150%	1.67a	4.61	6.25b

Notes: Values followed by the same letter in the same column indicate no significant difference based on the DMRT at α=0.05.

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2020). The provision of NPK significantly increased the growth of oil palm stem diameter in the nursery (Syamsuwirman et al., 2023).

Number of Leaflets

The 75% slow-release fertilizer dose increased the number of oil palm fronds in 8 months by 63.13% and 64.72% at 10 months after planting, compared to the 0% fertilizer dose treatment (Table 4). A study by Siallagan et al. (2014) reported that a compound NPK significantly increased the number of oil palm fronds in immature plants and resulted in a quadratic response at 9, 11, and 12 months after treatment, whereas in Hamidah and Noor (2024) study compound NPK significantly increased the number of leaves fronds.

Leaf Size, Leaflet Length, and Leaf Greenness Levels

The fertilizer dosage significantly affected the length of the fronds of oil palm seedlings in the main nursery. A 75% fertilizer dosage increased the length of plant fronds by up to 51% compared to the treatment without fertilization (Table 5). This is likely due to more nitrogen availability when fertilizer is applied. Compound NPK ensures the long-term availability of nitrogen because it is a slow-release fertilizer. Rasid et al. (2014) stated that providing slow-release fertilizers significantly increased leaf stem length.

Fertilizer dosage significantly affected the width and length of the fronds. A 75% fertilizer dosage increased the width of plant fronds by up to 52% compared to the treatment without fertilization and the leaflet length by 22% to control (Table 5).

Leaf formation of oil palm seedlings depends on the availability of nutrients, light intensity, and water (Adileksono et al., 2020). The leaf area reflects the area of the part that carries out photosynthesis; therefore, if the leaf area is higher, photosynthesis will also increase (Shintarika et al., 2015).

The fertilizer dosage significantly affected the level of leaf greenness in palm oil seedlings in the main nursery. A 75% fertilizer dosage increases the level of leaf greenness by up to 69.00% compared to the treatment without fertilization (Table 5). In a report by Sudradjat et al. (2015), the provision of NPK compound fertilizer packages to young (< 1 year old) oil palms significantly increased leaf area, leaf chlorophyll content, nitrogen, and phosphorus.

Plant Dry Weight

A 75% fertilizer dosage increased the plant's dry weight by 26.90% compared to the control (Table 6). Dry weight is a growth parameter that reflects the nutritional status of plants and assimilation through photosynthesis (Syahrovy et al., 2015). In a study by Ginting et al. (2021), the highest biomass accumulation in oil palms was found in the stems, followed by the roots and leaves.

The effects of NPK Mg compound fertilizer to the levels of N, P, K, and Mg nutrients in the leaves is shown in Table 4. The results of the leaf tissue analysis showed that the concentration of tissue nutrients for growth was in the sufficient zone when compared to those at the critical nutrient levels. It is not yet mature for 2.50% N (Ollagnier and Ochs, 1981). The leaf N level from the control treatment did not exceed the critical N limit at 10 months after planting.

The optimum concentrations of P and K in palm oil leaves are 0.165% and 0.9-1.3% (Foster et al., 1988). The results of the analysis of leaf P content in Table 4 were almost all below the optimum concentration.

Table 4. Leaf stalk length and width, leaflet length, and leaf greenness level 10 months after planting

Treatments	Leaf length (cm)	Leaf width (cm)	Leaflet length (cm)	Leaf greenness level [1)]
Control (without fertilizer)	54.48 c	0.87 d	24.61 b	46.20 c
Standard fertilizer 50%	65.08 bc	0.96 bcd	27.04 ab	42.12 c
Standard fertilizer 100%	67.45 bc	1.05 bcd	28.90 a	71.75 a
Slow-release fertilizer 25%	66.66 bc	0.93 cd	27.04 ab	47.52 c
Slow-release fertilizer 50%	69.67 ab	1.08 bcd	28.85 a	55.65 bc
Slow-release fertilizer 75%	82.56 a	1.33 a	30.26 a	78.20 a
Slow-release fertilizer 100%	73.50 ab	1.13 abc	28.98 a	74.67 a
Slow-release fertilizer 125%	65.74 bc	1.10 bcd	28.11 a	69.82 ab
Slow-release fertilizer 150%	70.49 ab	1.18 ab	30.09 a	78.57 a

Notes: [1)] = based on the SPAD values. Values followed by the same letter in the same column indicate no significant difference based on the DMRT at α=0.05.

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Table 4 shows that only slow-release fertilizer 100% resulted in the leaf optimum K value of 0.9%. The leaf analysis method is sensitive enough to detect depletion of soil reserves that cannot be measured by soil analysis, which aims to avoid the risk of over-fertilization without deviating significantly from the maximum results (Dubos et al., 2019). According to Obi et al. (2022), the amount of fertilizer applied will significantly increase nutrient absorption. Nitrogen is a major component of chlorophyll, which is required for photosynthesis. Increased nitrogen levels during the vegetative growth stage can strengthen and support root growth, allowing plants to take up more water and nutrients. This causes plants to grow faster and produce leaves, resulting in high productivity (Sudradjat, 2020). Nitrogen-deficient plants are generally small and slow-growing; older leaves turn yellow or pale green owing to a lack of chlorophyll, starting at the lower leaf tips and eventually spreading throughout the plant (Sudradjat, 2020). It is difficult to identify symptoms of P deficiency in palm oil plants. However, P deficiency may cause stunted plant growth, characterized by short fronds and pyramid-shaped stems (Sudradjat, 2020). Potassium deficiency appears in oil palm plants as orange spots, yellowing of the crown center, and white stripes (Sudradjat, 2020). The initial symptoms of magnesium deficiency appear with a color change from green to dark yellow on leaf stalks; the color change occurs especially on leaf stalks exposed to direct sunlight. Under severe deficiency conditions, the leaves change from dark yellow to bright yellow and then dry out (Sudradjat, 2020).

Relative Agronomic Effectiveness

Relative agronomic effectiveness compares the relative agronomic effectiveness of each fertilizer tested with that of a standard fertilizer. Relative agronomic effectiveness compares the increase in crop yield after treatment with the tested fertilizers and the increase in crop yield with standard fertilizer multiplied by 100 % (Machay et al., 1984). The recommended fertilizer in this study was the standard fertilizer treatment of 100% dose. Fertilizers are considered agronomically effective if their relative effectiveness value exceeds 95%.

Table 6. Oil palm leaf nutrient levels 10 months after planting

Treatments	Leaf N (%)	Leaf P (%)	Leaf K (%)	Leaf Mg (%)
Control	2.31	0.16	0.61	0.39
Standard fertilizer 50%	2.50	0.14	0.54	0.44
Standard fertilizer 100%	2.67	0.15	0.76	0.36
Slow-release fertilizer 50%	2.73	0.15	0.83	0.37
Slow-release fertilizer 100%	2.71	0.14	0.90	0.39

Notes: Values followed by the same letter in the same column indicate no significant difference based on the DMRT at α=0.05.

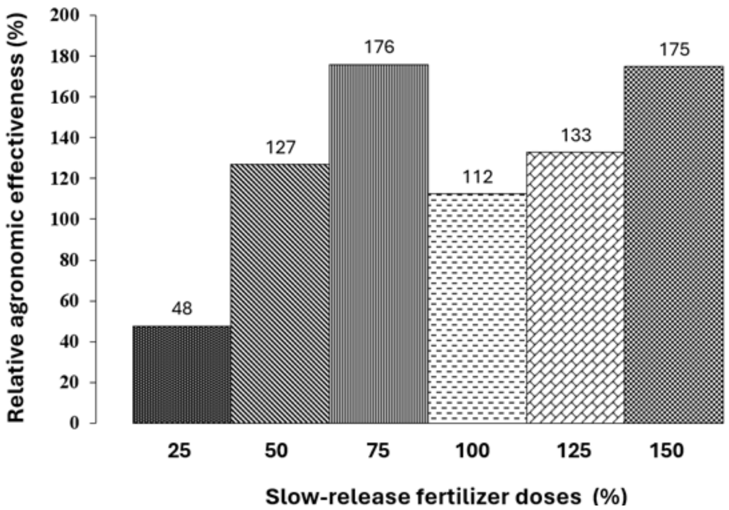

Figure 2. Relative agronomic effectiveness values (calculated based on Machay et al., 1984) of different doses of slow-release fertilizer.

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The calculation results of the relative agronomic effectiveness value (Figure 2) show that the slow-release fertilizer at 50% has reached agronomic effectiveness of >95%. Compared with conventional fertilizer treatments, solid compound slow-release fertilizers can reduce the amount of fertilizer for oil palm farmers because of the increased fertilization efficiency by 50-60% to obtain the same FFB production (Figure 2); a similar finding is reported by Wigena et al. (2006). These findings confirmed the results of Purnama and Afrillah (2022) that ensuring nutrient availability in oil palm seedlings at an early young age improved the growth of oil palm seedlings.

Conclusions

Slow-release fertilizers significantly affect the growth of oil palm seedlings at a dose of 75%. The slow-release fertilizer doses of 50% to 150% produced oil palm seedling growth that was at least as good as the standard fertilizer comparison and significantly better than the control, producing relative agronomic effectiveness above 95%.

References

Adileksana, C., Yudono, P., Purwanto, B.H., and Wijoyo, R.B. (2020). Growth performance of oil palm seedlings at the pre-nursery and main nursery stages as a response to the substitution of NPK compound fertilizer and organic fertilizer. *Caraka Tani: Journal of Sustainable Agriculture* **35**, 89-97. DOI: https://doi.org/10.20961/carakatani.v35i1.33884.

Ariyanti, M., Natalia, G., and Suherman, C. (2017). Response of oil palm seedling growth (*Elaeis guineensis* Jacq,) to the provision of organic fertilizer from oil palm fronds and NPK compound fertilizer. *Journal of Agriculture* **28**, 64-67. DOI: https:doi.org/10.24198/agrikultura.v28i2.14955.

Cole, J.C., Smith, M.W., Pen, C.J., Cheary, B.S., and Conaghan, K.J. (2016). Nitrogen, phosphorus, calcium, and magnesium applied separately or as slow-release or controlled-release fertilizers enhance growth and yield and affect macronutrient and micronutrient concentrations and contents in field-grown tomato plants. *Scientia Horticulturae* **211**, 420-430. DOI: https://doi.org/10.1016/j.scienta.2016.09.028.

Dubos, B., Baron, V., Bonneau, X., Dassou, O., Flori, A., Impens, R., Ollivier, J., and Pardon, L. (2019). Precision agriculture in oil palm plantations: a diagnostic tool for sustainable N and K nutrient provision. *OCL: Oilseeds and Fats, Crops and Lipids* **26**, 1-8. DOI: https://doi.org/10.1051/ocl/2019001.

Farrasati, R., Pradiko, I., Rahutomo, S., and Ginting, E.N. (2021). Fertilization through soil and leaves and its possible mechanisms in oil palm plants. *WARTA Palm Oil Research Center* **26**, 7-19.

Foster, H.L., Tarmizi, A.M., Tayeb, M.D., and Zakaria, Z.Z. (1988). Response of oil palm yield to P fertilizer in Peninsular Malaysia. *PORIM Bulletin* **17**, 1-8.

Ginting, E.N., Rahutomo, S., Farrasati, R., and Pradiko, I. (2021). Distribution of macronutrients (N, P, K, Mg) from single and compound fertilizers on oil palm seedlings (*Elaeis guineensis* Jacq.). *Agricultural Science* **6**, 10-19. DOI: https://doi.org/10.22146/ipas.60205.

Hamidah, H., and Noor, R.B. (2024). The effect of giving household waste trichocompost and rainbow NPK on the growth of oil palm seedlings (*Elaeis guineensis* Jacq.) in pre-nurseries. *AGRIFARM: Jurnal Ilmu Pertanian* **13**, 46–51. DOI: https://doi.org/10.24903/ajip.v13i1.3080.

Ibragimov, A., Sidique, S.F., and Tey, Y.S. (2019). Productivity for sustainable growth in Malaysian palm oil production: a system dynamics modeling approach. *Journal of Cleaner Production* **213**, 1051–1062. DOI: https://doi.org/10.1016/j.jclepro.2018.12.113.

Kamal, N.H.N., and Manan, F.A. (2020). Photosynthesis-related properties of oil palm leaves fertilized with different amounts. *International Journal of Life Sciences and Biotechnology* **3**, 70-80. DOI: https://doi.org/10.38001/ijlsb.697738.

Khalida, R., and Lontoh, A.P. (2019). Fertilization management of oil palm (*Elaeis Guineensis* Jacq.), case study on the Sungai Sagu Estate, Riau. *Buletin Agrohorti* **7**, 238-245. DOI: https://doi.org/10.29244/agrob.7.2.238-245.

Liu, Y., Xu, C., Li, Q., and Zhou, A. (2020). Interference competition for mutualism between ant species mediates ant-whitefly associations. *Insects* **11**, 91. DOI: https://doi.org/10.3390/insects11020091.

Received 14/10/2024; Revised 10/01/2025; Accepted 25/02/2025
https://doi.org/10.29244/jtcs.12.01.254-260

Machay, A.D., Syers, J.K., and Gregg, P.E.H. (1984). The ability of chemical extraction procedures to assess the agronomic effectiveness of phosphate rock materials. *New Zealand Journal of Agricultural Research* **27**, 219-230. DOI: https://doi.org/10.1080/00288233.1984.10430424.

Mangoensoekarjo, S. (2013). "Palm Oil Agribusiness Management". 650 pp. Gadjah Mada University Press.

Ministry of Agriculture of the Republic of Indonesia. (2022). "National Superior Plantation Statistics 2020-2022". Jakarta: Ministry of Agriculture of the Republic of Indonesia.

Ningsih, E.P., Sudrajat, and Supijatno. (2015). Optimization of calcium and magnesium fertilizer dosage on oil palm seedlings (*Elaeis guineensis* Jacq.) in the main nursery. *Jurnal Agronomi Indonesia* **43**, 81–88. DOI: https://doi.org/10.24831/jai.v43i1.9596.

Obi, E.A., Agele, S.O., Aiyelari, O.P., Adejoro, S.A., and Agbona, A.I. (2022). Nutrient uptake and utilization efficiency of cassava, corn, and pepper as influenced by fertilizer type and oil palm land age in oil palm-based intercropping system. *Journal of Soil Science and Environmental Management* **13**, 23–35. DOI: https://doi.org/10.5897/JSSEM2020.0818.

Ollagnier, M., and Ochs, R. (1981). Mineral nutrition management in industrial oil palm plantations. *Oléagineux* **36**, 409-421.

[PPKS] Pusat Penelitian Kelapa Sawit. (2014). "Petunjuk Teknis Pembibitan Kelapa Sawit". Medan.

Purnama, H., and Afrillah, M. (2022). Analysis of oil palm seedling growth at the pre-nursery and main nursery stages at PT. Socfindo. *Community Service: Journal of Research and Community Service* **3**, 251-257. DOI: https://doi.org/10.36418/dev.v3i5.127.

Rasid, M.N.A., Chek, T.C., and Redzuan, A.F. (2014). Effectiveness of urea-coated fertilizer on the growth of immature young oil palms. *Journal of Advanced Agricultural Technology* **1**, 56-59. DOI: https://doi.org/10.12720/joaat.1.1.56-59.

Santi, L.P., and Goenadi, D.H. (2016). Organo-chemical fertilizers for fertilizing oil palm seedlings organochemical fertilizers for fertilizing oil palm seedlings. *Jurnal Menara Perkebunan* **76**, 36-46. DOI: https://doi.org/10.22302/iribb.jur.mp.v76i1.94.

Shintarika, F., Sudrajat, and Supijatno. (2015). Optimizing nitrogen and phosphorus fertilizer for one-year-old oil palm (*Elaeis guineensis* Jacq.). *Jurnal Agronomi Indonesia* **43**, 250–256. DOI: https://doi.org/10.24831/jai.v43i3.11252.

Siallagan, I., Sudrajat, and Hariyadi. (2014). Optimizing organic and compound NPK fertilizer for one-year-old oil palm (*Elaeis guineensis* Jacq.). *Jurnal Agronomi Indonesia* **42**, 166–172.

Sudradjat, Darwis, A., and Wachjar, A. (2014). Optimization of nitrogen and phosphorus fertilizer doses on oil palm seedlings (*Elaeis guineensis* Jacq.) in the main nursery. *Jurnal Agronomi Indonesia* **42**, 222-227. DOI: https://doi.org/10.24831/jai.v42i3.9178.

Sudradjat, Saputra, H., and Yahya, S. (2015). Optimization of NPK compound fertilizer dosage on one-year-old oil palm (*Elaeis guineensis* Jacq.). *International Journal of Sciences: Basic and Applied Research (IJSBAR)* **20**, 365-372.

Sudradjat. (2020). "Palm Oil: Prospects for Development and Productivity Improvement". Bogor. IPB Press.

Sulardi. (2022). "Oil Palm Cultivation." PT Dewangga Energi Internasional. Medan.

Syahrovy, M., Purba, A., Hidayat, T.C., and Hidayat, F. (2015). Respons of oil palm seedling growth to liquid fertilizer of cattle urine application. *Jurnal Pendidikan Kelapa Sawit* **23**, 137-145.

Syamsuwirman, Meriati, and Kaumi, H. (2023). Pengaruh pemberian pupuk NPK 16:16:16 yaramila terhadap pertumbuhan bibit kelapa sawit (*Elaeis guineensis* Jacq) pada fase main-nursery. *Journal of Agricultural Science Research* **3**, 52-59. DOI: https://doi.org/10.31933/wnw15x89.

Wigena, I.G.P., Purnomo, J., Tuherkih, E., and Saleh, A. (2006). Effect of solid compound "slow release" fertilizer on growth and production of young oil palm on Xanthic Hapludox in Merangin, Jambi. *Journal of Soil and Climate* **24**, 10-19.