AGROMIX, Volume 16 Number 1 (2025), Pages 44–50

AGROMIX
pISSN (Print): 2085-241X; eISSN (Online): 2599-3003
Website: https://jurnal.yudharta.ac.id/v2/index.php/agromix

Enhancing oil palm seedling growth through the utilization of guano in the early nursery stage

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Original article

Article history
Received : November 22, 2023
Accepted : February 15, 2025
Published : March 31, 2025

Keyword
Guano
Oil palm seedling
Pre-Nursery
Phosphorus
Vermicompost

ABSTRACT

Introduction: Oil palm nurseries are crucial to oil palm farming success. Thus, precise management measures from the start, such as giving nutrients and using optimal planting material, are essential. Vermicompost and guano were tested as organic fertilizers in oil palm fields to replace chemical fertilizers. This study aims to evaluate the effect of guano and vermicompost as organic fertilizers on the growth of oil palm seedlings during the pre-nursery stage. **Methods:** Besides the control group, the experimental treatments included 10% vermicompost, 20% vermicompost, 10% guano, and 20% guano, each replicated five times in a completely randomized design. **Results:** The introduction of 10% guano resulted in a significant enhancement across key growth metrics Addition of 10% guano had 20.0% more leaves, 22.5% more stem diameter, and 62.1% more shoot dry weight than the control group. This study shows that guano, which includes 19% P_2O_5, can boost oil palm seedling growth. The inceptisols were already rich in nutrients, thus vermicompost did not affect it throughout the three-month testing. Since the soil conditions were good, vermicompost did not change them during the three-month trial. The correlation matrix showed a strong and constant link between seedling shoot and root fresh and dry weights. The relationship between organic fertilizers and oil palm nursery growth highlights the importance of a well-rounded plant development profile. This highlights the complex relationship between organic fertilizers and oil palm growth. **Conclusion:** Guano at 10% has been shown to improve oil palm seedling growth in the nursery phase, outperforming vermicompost.

Cite this article:
Kautsar, V., Afrizal, & Parwati, W. D. U. (2025). Enhancing oil palm seedling growth through the utilization of guano in early nursery stage. *AGROMIX, 16*(1), 44–50. https://doi.org/10.35891/agx.v15i2.4527

INTRODUCTION

Palm oil is one of the leading commodities that plays a very important role in Indonesia's plantation sector. Over the past 20 years, the area of oil palm plantations has been increasing in various schemes, both large plantations, nucleus plasma estates, and profit-sharing partnerships (Kautsar, *et al.*, 2022; Safitri *et al.*, 2018; Santika *et al.*, 2019; Xu *et al.*, 2020). In 1980, the area of oil palm plantations in Indonesia was only 204 thousand hectares, then increased to 673 thousand hectares in 1990, 2 million hectares in 2000, 8.4 million hectares in 2010, and further increased to over 15 million hectares in 2021. The increasing demand for vegetable oil and all its by-products has led to extraordinary growth in this commodity. This growth is not only in Indonesia but also globally. In 2021, the global oil palm plantation area reached 29 million hectares, an increase of 576% compared to 1980, which was only 4.3 million hectares (FAOSTAT, 2023; Xu *et al.*, 2020).

This increased demand also affects the availability of high-quality seedlings in abundance. Generally, oil palm seedlings are divided into two systems: the single-stage system and the double-stage system. The single-stage system involves germinating seedlings in one polybag from the beginning until they are one year old before being transplanted to the field. Meanwhile, the double-stage system involves two stages: the first 3 months in the pre-nursery stage, followed by transplanting the seedlings to larger polybags in the main nursery until they are 12 months old before being transplanted to the field. Typically, companies prefer the double-stage system because it produces much higher quality and uniform seedlings. The initial nursery stage is the most crucial phase that influences the growth and production of oil palm trees for approximately 25 years. Therefore, providing high-quality seedlings in the initial nursery stage is the best step to support production optimization and achieve the expected potential yield (Kautsar *et al.*, 2022; Lubis & Widanarko, 2011; Pahan, 2021).

The growth of oil palm seedlings relies on three essential factors: water availability, air, and nutrients. These requirements are met through the planting medium, typically mineral soil. The planting medium commonly used is mineral soil, which sometimes may not adequately supply the plant's needs due to its low physical, chemical, or biological fertility. Typically, in oil palm plantations, nutrients are provided in the form of chemical fertilizers during the pre-nursery stage. Fertilization with synthetic fertilizers only improves chemical fertility, while physical and biological fertility remains unchanged. Therefore, with increasing awareness of the importance of soil physical and biological fertility, fertilization is now not only focused on the use of synthetic fertilizers but also supplemented with organic fertilizers (Lubis & Widanarko, 2011; Pahan, 2021; Safitri *et al.*, 2018). Fertilizer application is a primary activity in seedling nurseries. The materials and types of fertilizers used for oil palm seedling nurseries vary significantly. This diversity arises from the fact that fertilizer recommendations can differ between oil palm nurseries operated by different companies or farmers due to variations in management practices, soil types, palm varieties, or other influencing factors (Laksono *et al.*, 2019).

Numerous studies have demonstrated that the application of organic fertilizers can enhance various soil properties. These include the ability to retain water (water holding capacity), cation exchange capacity, improvement of porosity, aeration, nitrogen mineralization, soil pH, as well as increasing the activity, quantity, and diversity of microorganisms in the soil (Kautsar *et al.*, 2020; Kautsar *et al.*, 2022; Wijayanti & Setyandito, 2018). During the early seedling stage, the application of organic fertilizers is highly suitable because the nutrient requirements of the seedlings are not very high. Therefore, organic fertilizers have significant potential to replace the inorganic fertilizers commonly used in seedling nurseries. Commonly used organic fertilizers include manure, compost, empty fruit bunches, vermicompost, and guano. Vermicompost, derived from earthworm castings, offers several advantages. It contains various nutrients, including 3.04%–4.26% nitrogen, 0.78-1.28 g kg^{-1} P_2O_5, and 3.7-7.3 g kg^{-1} K_2O. In addition to macronutrients, vermicompost also contains essential micronutrients such as iron (Fe), manganese (Mn), copper (Cu), and zinc (Zn), which are required by plants in varying amounts depending on the raw materials used to produce the vermicompost (Geremu *et al.*, 2020). Meanwhile, guano is a fertilizer derived from the excrement of birds or bats, rich in phosphorus content. The P_2O_5 content in guano can reach up to 19%, making it advantageous as phosphorus is one of the essential nutrients required by plants in large quantities (Emerson & Roark, 2007).

In the context of oil palm plantations in Indonesia, guano, due to its high phosphorus content, plays a crucial role in enhancing root development and overall plant vigor, particularly in nutrient-poor soils. Vermicompost, on the other hand, improves soil structure and microbial activity, which can be beneficial in maintaining soil health over time. The specific requirements of oil palm plantations, such as nutrient availability and sustainable management practices, make these organic fertilizers attractive alternatives to conventional chemical fertilizers. Due to the potential of organic fertilizers like vermicompost and guano to substitute chemical fertilizers in the primary nursery, there is a necessity for precise information concerning their effectiveness and influence on the growth of oil palm seedlings. Thus, this study aims to examine the impact of applying vermicompost and guano on the growth of oil palm seedlings during the initial nursery phase.

METHODS

Research design

The study was conducted between February and May 2022 using a completely randomized design. The treatments included were vermicompost at 10%, vermicompost at 20%, guano at 10%, guano at 20%, and a control. All percentages are based on weight ratios. Each treatment was replicated five times. The soil used was the upper layer of Inceptisol, sourced from Maguwoharjo, Depok, Sleman, and Yogyakarta.

Planting and cultivation management

The soil was sieved with a 2 mm mesh size to ensure uniformity and fine granules, then cleaned from stones and plant debris. Subsequently, the planting medium was supplemented with vermicompost and guano according to the specified dosage. Before seedling planting, polybags measuring 18x18 cm filled with the planting medium were watered until field capacity was reached. The polybags were placed inside a 4 x 2.5 m greenhouse covered with ultraviolet plastic and with a height of 2 meters. Simalungun variety seedlings were selected to obtain normal seedlings by observing opposite plumule and radicle directions, absence of fungal growth, and fresh appearance of plumule and radicle. Oil palm seedlings were planted by making holes in the planting medium to a depth of 3 cm, then inserting the seedlings into the holes with the plumule facing upwards and the radicle downwards.

The maintenance of oil palm seedlings is carried out by watering twice a day, in the morning and afternoon, with a volume of 50 ml each time. Weeding is done regularly to prevent weeds from interfering with the growth of oil palm seedlings. Pest control is done manually by picking pests. During the study, no plant pests were found to cause damage to the main plants.

Plant parameters

The parameters observed include plant height, leaf number, stem diameter, shoot fresh weight, shoot dry weight, fresh weight of roots, dry weight of roots, and root volume. Measurements of plant height and leaf number were taken 3 weeks after planting and then observed weekly until the end of the early nursery stage, specifically at week 12 after planting. Observations for other parameters were conducted at the end of the early nursery stage or week 12 after planting. Plant height was determined by measuring from the bottom of the stem to the top. The leaf number was determined by counting fully opened leaves. At the end of the study, the shoot and root fresh weight were determined using an analytical balance. After the plant samples were dried in an oven at 70°C for 48 hours, the dry weight of both shoot and root samples was determined.

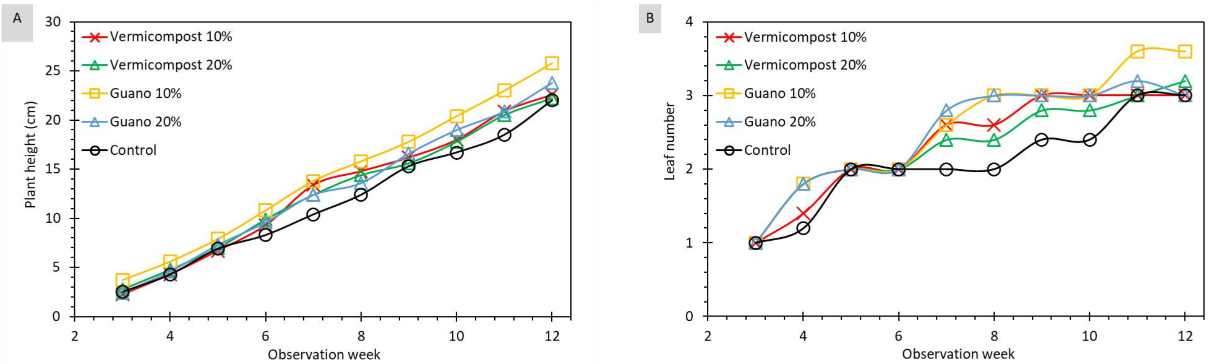
Statistical analysis

The research data were analyzed for homogeneity and normality using the Shapiro-Wilk test. Subsequently, the data were analyzed using one-way Analysis of Variance (ANOVA) at a 5% significance level to determine whether there were any significant effects. If significant effects were found, a post-hoc Tukey HSD (Honestly Significant Difference) test was conducted at a 5% significance level. All statistical analyses were performed using IBM SPSS Statistics version 26 (IBM Corp., Armonk, New York, USA). Pearson correlation matrix was generated using Python version 3.12.2 (Python Software Foundation, Wilmington, Delaware, USA) accessed via Jupyter Notebook version 6.4.8 (Project Jupyter, Berkeley, California, USA).

RESULTS AND DISCUSSIONS

Plant growth

The application of 10% guano fertilizer has already shown a higher plant growth rate in the third week compared to other treatments. The growth rate of plants with 10% guano application consistently remained higher until the last week of observation. Meanwhile, the control group exhibited the lowest value compared to other treatments (Figure 1A). Based on statistical analysis results, no significant differences were observed between the 10% guano treatment and other treatments in the last week (Table 1). The leaf number parameter showed variations across all treatments from the third week until the end of the observation period (Figure 1B). At the end of the observation period, it was evident that 10% guano significantly increased the leaf number compared to 10% vermicompost, 20% guano, and the control group (Table 1). This finding differs from previous research conducted by Muryanto & Lidar (2020) that found the application of 0.5 kg polybag^{-1} guano fertilizer significantly increased the height of oil palm seedlings in the pre-nursery stage. However, it did not significantly affect the leaf number or stem diameter.



Vermicompost 10%	2,2	4,3	6,7	9,3	13,4	14,8	16,2	18,0	20,9	22,6
Vermicompost 20%	2,8	4,8	7,0	9,9	12,4	14,4	15,6	17,8	20,5	22,2
Guano 10%	3,7	5,6	7,9	10,8	13,8	15,8	17,8	20,4	23,0	25,8
Guano 20%	2,4	4,6	7,3	9,6	12,4	13,6	16,6	19,0	20,9	23,8
Control	2,5	4,3	6,9	8,3	10,4	12,4	15,3	16,7	18,5	22,0

Vermicompost 10%	1,0	1,4	2,0	2,0	2,6	2,6	3,0	3,0	3,0	3,0
Vermicompost 20%	1,0	1,8	2,0	2,0	2,4	2,4	2,8	2,8	3,0	3,2
Guano 10%	1,0	1,8	2,0	2,0	2,6	3,0	3,0	3,0	3,6	3,6
Guano 20%	1,0	1,8	2,0	2,0	2,8	3,0	3,0	3,0	3,2	3,0
Control	1,0	1,2	2,0	2,0	2,0	2,0	2,4	2,4	3,0	3,0

Figure 1. The effect of vermicompost and guano on the growth rate of oil palm seedlings (A) and leaf number (B) in the early nursery stage.

The stem diameter showed that the addition of both 10% and 20% guano resulted in significantly better growth, with diameters of 7.40 ± 1.08 mm and 7.68 ± 1.16 mm, respectively, compared to the control, which only had a diameter of 6.04 ± 0.37 mm (Table 1). Meanwhile, vermicompost at both 10% and 20% doses did not show a significant difference compared to guano and the control. This could be because, during the initial growth of oil palm seedlings, the planting medium was already sufficient to support growth, so improving the planting medium through the addition of vermicompost did not have a significant effect. This appears to be different from research conducted in the main nursery, where soil conditions become one of the inhibiting factors for plant root development. The addition of vermicompost in relatively large amounts (300 g polybag^{-1}) was found to improve the growth of oil palm seedlings in the main nursery (Kautsar *et al.*, 2022). Earthworms effectively manage organic waste and produce biofertilizers through vermicomposting, reducing the C:N ratio while retaining more nutrients compared to traditional composting (Bhat *et al.*, 2018). However, it should be noted that while earthworm applications improve soil quality and enhance nutrient availability for plants, research by Mahmud *et al.*, (2018) indicates smaller fruit sizes compared to chemical fertilizers.

The root volume showed no significant differences among all treatments. Generally, root volume ranged from 1.0 to 1.6 cm3 (Table 1). Root volume in the pre-nursery stage tended not to show significant differences among the treatments. This is also supported by other research, such as Damanik *et al.*, (2023) and Sipayung *et al.* (2023), which showed no treatment effects on root volume.

Table 1. The effect of vermicompost and guano on the height, leaf number, stem diameter, and root volume of oil palm seedlings at 12 weeks after planting.

Treatment	Plant height (cm)	Leaf number	Stem diameter (mm)	Root volume (cm^3)
Vermicompost 10%	22.6 ± 2.88 a	3.0 ± 0.0 b	6.58 ± 0.57 ab	1.0 ± 0.0 a
Vermicompost 20%	22.2 ± 1.30 a	3.2 ± 0.4 ab	7.18 ± 0.87 ab	1.6 ± 0.5 a
Guano 10%	25.8 ± 3.77 a	3.6 ± 0.5 a	7.40 ± 1.08 a	1.2 ± 0.4 a
Guano 20%	23.8 ± 4.49 a	3.0 ± 0.0 b	7.68 ± 1.16 a	1.4 ± 0.5 a
Control	22.0 ± 1.58 a	3.0 ± 0.0 b	6.04 ± 0.37 b	1.0 ± 0.0 a

Remarks: Values are means ± standard deviation. The same letter in the same column indicates no significant difference based on the Tukey HSD test at 5% significance level.

Fresh and dry weight of shoot and root

The shoot fresh weight did not show significant differences among all treatments, with a range of shoot fresh weight from 3.54 to 5.19 g (Figure 2A). The application of 10% guano showed the highest shoot dry weight at 1.07 g, significantly higher than vermicompost 10%, vermicompost 20%, and control, which showed values of 0.71, 0.81, and 0.66 g, respectively. Meanwhile, 20% guano had a shoot dry weight of 0.91 g, indicating no significant difference compared to all other treatments (Figure 2B). Significant effects of guano addition on oil palm growth were also found in the study (Muryanto & Lidar, 2020). In addition to oil palm seedlings, research by Utami *et al.* (2021) also showed significant effects of guano on the growth of *Phaseolus vulgaris* L.

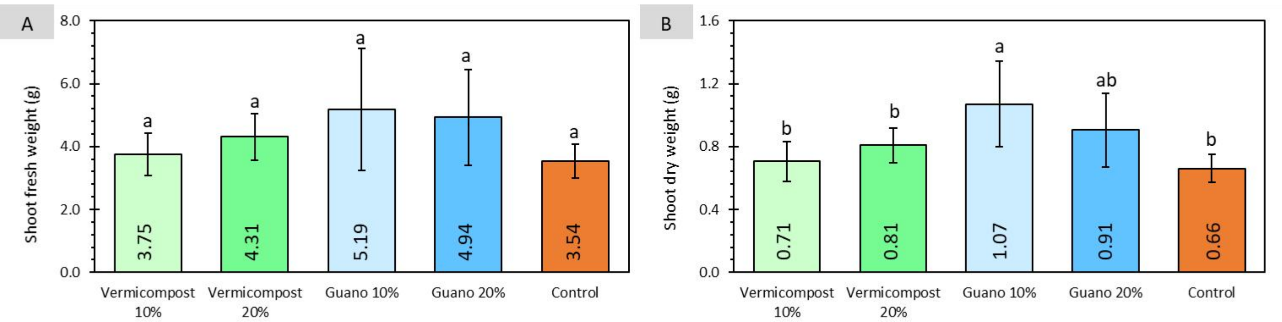


Figure 2. The effect of vermicompost and guano on the shoot fresh weight (A) and shoot dry weight(B) in the early nursery stage of oil palm seedlings. The bars indicate the standard deviation. The same notation indicates no significant difference based on the Tukey HSD test at 5% significance level.

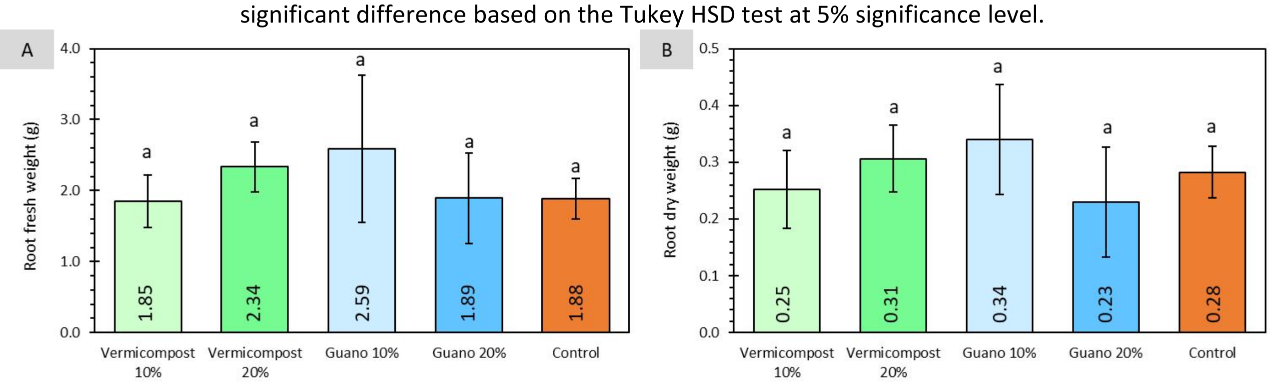


Figure 3. The effect of vermicompost and guano on the fresh weight of roots (A) and dry weight of roots (B) in the early nursery stage of oil palm seedlings. The bars indicate the standard deviation. The same notation indicates no significant difference based on the Tukey HSD test at 5% significance level.

The fresh weight of oil palm seedling roots in the early nursery stage showed no significant differences among all treatments. Generally, root fresh weight ranged from 1.85 to 2.59 g (Figure 3A). The same pattern was observed for root dry weight, which did not differ significantly among all treatments, with values ranging from 0.23 to 0.34 g (Figure 3B).

The superior effect of 10% guano on plant growth can be attributed to its high phosphorus content (19% P_2O_5), which is critical for root development and energy transfer in plants. This could have promoted more vigorous growth compared to other treatments. Additionally, the better performance of 10% guano over 20% guano may be due to the potential negative effects of excess phosphorus at higher concentrations. While phosphorus is an essential nutrient, excessive amounts, such as in the 20% guano treatment, may disrupt the balance of other vital nutrients, such as nitrogen and potassium, leading to reduced growth. The 10% guano likely provided an optimal balance of phosphorus, promoting growth without hindering nutrient absorption. The lack of a significant response to vermicompost may also be due to the nutrient-rich inceptisols used in the study, which already supplied adequate nutrient levels, thus masking any potential benefits of vermicompost during the short-term trial.

Correlation matrix

The relationship between growth parameters of oil palm seedlings at the early nursery stage was analyzed using Pearson correlation. The aim was to determine the parameters that are interrelated and can be indicators of growth. The parameters analyzed included plant height (PH), number of leaves (LN), stem diameter (SD), fresh and dry weight of the crown (SFW, SDW), fresh and dry weight of roots (RFW, RDW), and root volume (RV). The results of the analysis are presented in matrix form to show the strength and direction of the relationship between variables.

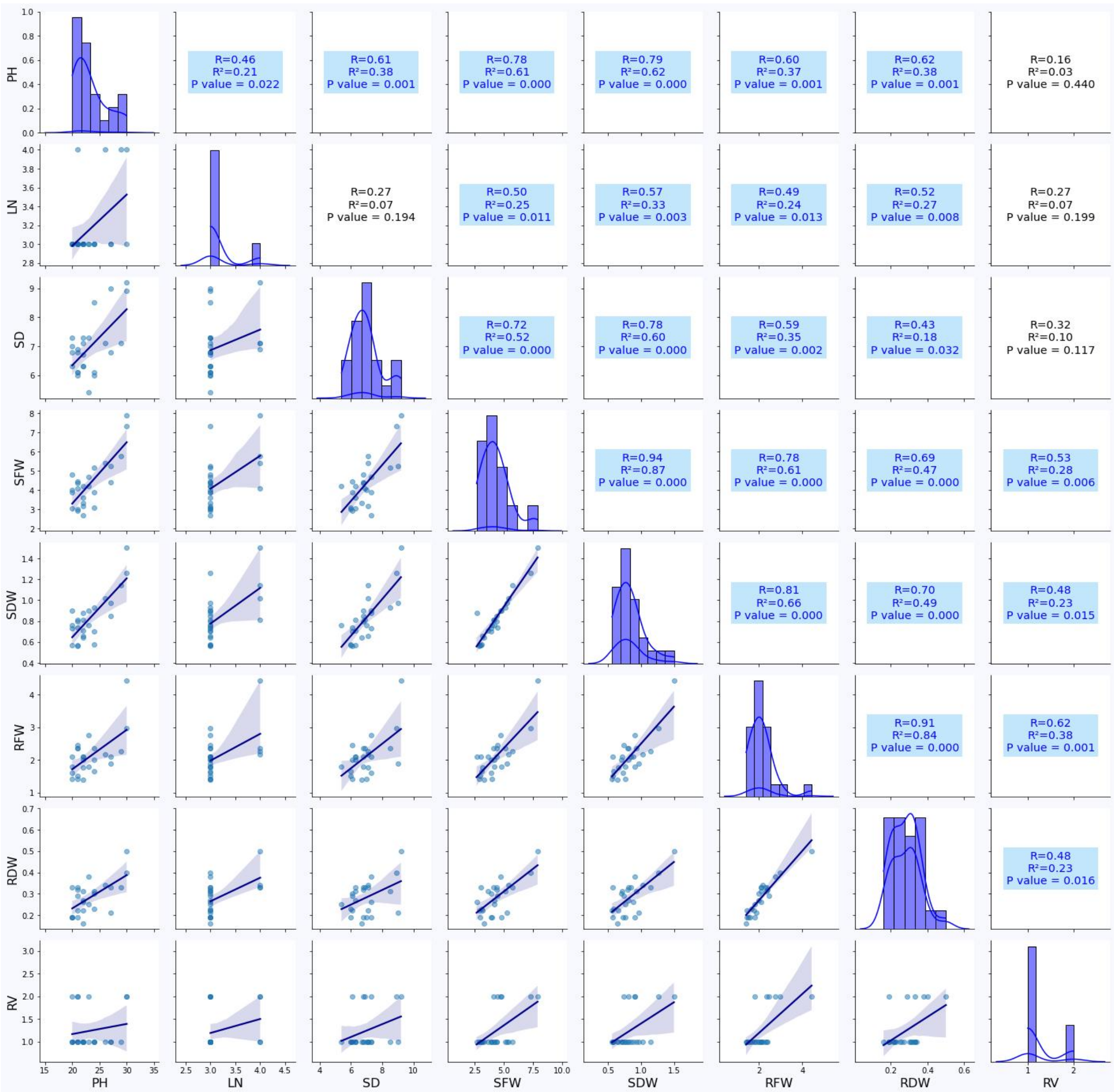


Figure 4. Pearson correlation matrix of oil palm seedling parameters in the early nursery stage. The numbers in the columns indicate the correlation coefficients. PH: plant height, LN: leaf number, SD: stem diameter, SFW: shoot fresh weight, SDW: shoot dry weight, RFW: root fresh weight, RDW: root dry weight, RV: root volume

Most of the analyzed parameters show significant correlations (Figure 4). Both the fresh and dry weights of the shoot and roots overall exhibit positive and highly significant correlations (P<0.001), with the highest correlation observed between the fresh weight and dry weight of the shoot, with a correlation coefficient of 0.94. This indicates that an increase in the shoot fresh weight of oil palm seedlings will be followed by an increase in their dry weight. The strong correlation (r = 0.94) between shoot fresh and dry weights suggests a direct relationship between shoot biomass accumulation and water content. This high correlation underscores the importance of shoot growth as an indicator of overall plant health. Plant height generally shows significant correlations with all parameters, except for root volume. The lack of a significant correlation between root volume and other parameters might be due to the minimal variability in root development at the pre-nursery stage, where root volume does not yet play a major role in supporting shoot growth. Plant height has the strongest correlation with the shoot fresh weight and dry weight, with correlation coefficients of 0.78 and 0.79, respectively. Similarly, the stem diameter parameter has correlation coefficients of 0.72 (P<0.001) and 0.78 (P<0.001) with the shoot fresh weight and dry weight, respectively. This indicates that each parameter is interrelated and influences other parameters.

The relationship between shoot and roots, both in terms of fresh weight and dry weight, provides morphological information about the plant. The proximity of the relationship suggests that an increase in root quantity correlates with improved shoot weight. The shoot dry weight of oil palm seedlings is determined by the plant's root activity in transporting water and nutrients to the entire plant body. Because the absorption of minerals is partially controlled by the shoot, the process begins with the shoot stimulating the roots to increase mineral absorption. These minerals will be utilized by the plant in the formation of various proteins, nucleic acids, and chlorophyll found in the leaves. In addition, the shoot will supply carbohydrates through the phloem, which are used as raw materials in respiratory activities that ultimately produce Adenosine Tri Phosphate (ATP) (Pessarakli, 2002; Starr *et al.*, 2010).

CONCLUSION

The addition of 10% guano significantly increased the leaf number, stem diameter, and shoot dry weight of oil palm seedlings in the pre-nursery stage. This indicates that guano can be utilized to improve the quality of seedlings in the pre-nursery stage. Meanwhile, vermicompost has not shown a significant effect on the growth of oil palm seedlings. This could be because the initial growth of seedlings may already have sufficient nutrients from food reserves, in addition to the nursery media providing adequate water and air for the plants.

REFERENCES

Bhat, S. A., Singh, J., & Vig, A. P. (2018). Earthworms as organic waste managers and biofertilizer producers. *Waste and Biomass Valorization, 9*(7), 1073–1086. https://doi.org/10.1007/s12649-017-9899-8

Damanik, A. (2023). *Pengaruh macam dan konsentrasi pupuk organik cair (bioslury, serum, urin) terhadap pertumbuhan bibit kelapa sawit* [Thesis]. Institut Pertanian Stiper Yogyakarta.

Emerson, J. K., & Roark, A. M. (2007). Composition of guano produced by frugivorous, sanguivorous, and insectivorous bats. *Acta Chiropterologica, 9*(1), 261–267. https://doi.org/10.3161/1733-5329(2007)9[261:COGPBF]2.0.CO;2

FAOSTAT. (2023). *Food and agriculture organization of the united nations.* Crops and livestock products.

Geremu, T., Hailu, H., & Diriba, A. (2020). Evaluation of nutrient content of vermicompost made from different substrates at Mechara Agricultural Research Center on the station, West Hararghe Zone, Oromia, Ethiopia. *Ecology and Evolutionary Biology, 5*(4), 125-137. https://doi.org/10.11648/j.eeb.20200504.12

Kautsar, V., Cheng, W., Tawaraya, K., Yamada, S., Toriyama, K., & Kobayashi, K. (2020). Carbon and nitrogen stocks and their mineralization potentials are higher under organic than conventional farming practices in Japanese Andosols. *Soil Science and Plant Nutrition, 66*(1), 144–151. https://doi.org/10.1080/00380768.2019.1705739

Kautsar, V., Ismawanto, D., & Parwati, W. D. U. (2022). The response of oil palm seedlings' growth to vermicompost and water stress under the main nursery stage. *Jurnal Pertanian Tropik, 9*(3, Dec), 26-45. https://doi.org/10.32734/jopt.v9i3.9933

Kautsar, V., Tang, S., Kimani, S. M., Tawaraya, K., Wu, J., Toriyama, K., Kobayashi, K., & Cheng, W. (2022). Carbon decomposition and nitrogen mineralization of foxtail and milk vetch incorporated into paddy soils for different durations of organic farming. *Soil Science and Plant Nutrition, 68*(1), 158–166. https://doi.org/10.1080/00380768.2021.2024424

Laksono, N. D., Setiawati, U., Nur, F., Rahmaningsih, M., Anwar, Y., Rusfiandi, H., Forster, B. P., Sembiring, E. H., Subbarao, A. S., & Zahara, H. (2019). Fertiliser programmes. In *Nursery practices in oil palm: A manual* (pp. 55–61). CAB International. https://doi.org/10.1079/9781789242140.0055

Lubis, R. E., & Widanarko, A. (2011). *Buku pintar kelapa sawit*. AgroMedia.

Mahmud, M., Abdullah, R., & Yaacob, J. S. (2018). Effect of vermicompost amendment on nutritional status of sandy loam soil, growth performance, and yield of pineapple (Ananas comosus var. MD2) under field conditions. *Agronomy, 8*(9), Article 183. https://doi.org/10.3390/agronomy8090183

Muryanto, & Lidar, S. (2020). Guano fertilizer applications to improve the growth of palm oil seeds (Elaeis guineensis Jacq) in pre-nursery. *Jurnal Ilmiah Pertanian, 16*(2), 94-99. https://doi.org/10.31849/jip.v16i2.3608

Pahan, I. (2021). *Panduan budidaya kelapa sawit untuk pekebun*. Penebar Swadaya. https://cir.nii.ac.jp/crid/11300129 21456486020

Pessarakli, M. (Ed.). (2002). *Handbook of plant and crop physiology* (2nd ed., rev. expanded). M. Dekker.

Safitri, L., Hermantoro, H., Purboseno, S., Kautsar, V., Saptomo, S., & Kurniawan, A. (2018). Water footprint and crop water usage of oil palm (Elaeis guineensis) in Central Kalimantan: Environmental sustainability indicators for different crop age and soil conditions. *Water, 11*(1), 35-48. https://doi.org/10.3390/w11010035

Santika, T., Wilson, K. A., Budiharta, S., Law, E. A., Poh, T. M., Ancrenaz, M., Struebig, M. J., & Meijaard, E. (2019). Does oil palm agriculture help alleviate poverty? A multidimensional counterfactual assessment of oil palm development in Indonesia. *World Development, 120*, 105–117. https://doi.org/10.1016/j.worlddev.2019.04.012

Sipayung, D. A. (2023). Pengaruh konsentrasi dan cara aplikasi eco enzyme terhadap pertumbuhan bibit kelapa sawit di pre nursey [Tesis]. Institut Pertanian Stiper Yogyakarta.

Starr, C., Evers, C. A., & Starr, L. (2010). *Biology: Today and tomorrow: With physiology*. Brooks/Cole.

Utami, E. P., Heryani, I., & Chaidir, L. (2021). Pengaruh pupuk guano dan media tanam terhadap pertumbuhan dan hasil tanaman buncis tegak. *Jurnal AGRO, 8*(1), 13-25. https://doi.org/10.15575/10303

Wijayanti, Y., & Setyandito, O. (2018). Groundwater recharge pattern in agricultural area. *AGROISTA: Jurnal Agroteknologi, 1*(2), 1-10. https://doi.org/10.55180/agi.v1i2.21

Xu, Y., Yu, L., Li, W., Ciais, P., Cheng, Y., & Gong, P. (2020). Annual oil palm plantation maps in Malaysia and Indonesia from 2001 to 2016. *Earth System Science Data, 12*(2), 847–867. https://doi.org/10.5194/essd-12-847-2020