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Addition of Fungal Inoculum in Composting of Palm Oil Mill Effluent Sludge (PMOs) on Peanut (*Arachis hypogea* L.) Growth

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Abstract: *There is a huge amount of palm oil production waste in Indonesia that is usually not processed properly. In fact, this organic waste has great potential if properly degraded to be converted into plant nutrients. The addition of lignocellulolytic fungi as beneficial microbes that can improve the composting of Palm Oil Mill Sludge is an interesting study to explore.The purpose of this study was to determine the effect of Palm Oil Mill Sludge (POMS) sludge composting induced by Trichoderma sp. (lignocellulolytic isolate) on peanut plant growth. This research used Completely Randomized Design (CRD) with 7 compost dosagesand parameters observed were freshand dry weight, root : shoot ratio, and chlorophyll a, b, and total. Data were analyzed statistically with the ANOVA method and continued with the Least Significant Difference (LSD) test at the 5 % level The result demonstrate that compost induced by ligninolytic fungus (Trichoderma sp.) produced the optimal effect on growth paramaters across of all treatments.. The compost application could increase significantly fresh and dry weight, root : shoot ratio, and chlorophyll content of a, b, and total. The result of this research indicate that a combination of 98,4 % soil and 1,6 % compost produces the highest value compared to other treatmens.*

Keywords: *Palm Oil Mill Sludge (POMS), Trichodermasp, Compost, Arachis hypogaea L*

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I. INTRODUCTION

Oil palm plantations in Indonesia are quite abundant and the distribution is mostly on the island of Sumatra. Therefore, there are many industries engaged in palm oil processing. The palm oil industry will process palm oil into Crude Palm Oil (CPO). As a result of this processing, 75% of the waste from the dispos al of production activities will remain in the form of solid waste and liquid waste. Solid waste is in the form of empty bunches, fibers and shells, while liquid waste is in the form of POME (Palm Oil Mill Effluent) and sludge.

Production of Crude Palm Oil (CPO) increases every year. As a result of the CPO high production, waste generated has increased. The amount of waste produced reached 700 – 800 L/tons Fresh Fruit Bunches (FFB) (Winanti, 2019). POME sludge contains many organic compound such as 22,26 mg/L C-Organic, 457 mg/L Nitrogen, 12 mg/L Phoshorus, 56 mg/L Magnesium, and 375 mg/L Potassium (Sakiah and Wahyuni, 2018). In addition to organic compounds, the lignin content in POME sludge is also quite high, reaching 2900 - 7800 mg/L (Hii et al., 2011). As a complex phenolic polymer, lignin promotes minerals transport through the vascular bundles in plant and enchances plant cell wall rigidity (Scheutz et. al, 2014). In addition, lignin is an important barrier that protects against pathogens and pests (Ithal et al., 2007). For this reason, POME sludge can be used as compost (Ramli et al., 2016).

Lignin is a recalcitrant compound that is difficult to degrade biologically without the help of microorganis ms. In fact microorganisms that have lignolytic enzymes are needed in composting such as *Trichoderma* sp. (Irawan et al., 2023). *Trichoderma* sp. has laccase enzyme able to degrade the complex bonds of lignin (Sadhasivams et al., 2008). *Trichoderma* has the manganese peroxidase (MnP) enzyme and lignin peroxidase (LiP) enzyme. LiP is able to oxidize aromatic nuclei (phenolic and nonphenolic) through the release of one electron generating cation and phenoxy radicals. Meanwhile, Manganese peroxidase (MnP) is an external peroxidase enzyme that is able to degrade lignin using H_2O_2 (Hofrichter, 2002).

The presence of Trichoderma fungus inoculum in compost was able to increase soil fertility in terms of Nitrogen, Phosphorus and potassium soil content and plant growth (Irawan et al., 2017). One research has shown that application of compost induced by ligninolytic inoculum of *Trichoderma* sp. can increase vegetative growth plants (Haura et al., 2021). Besides, the use of POME compost mixed with manure can also increase the growth of plant height and number of leaves (Adela et al., 2014).

II. EXPERIMENTAL PROCEDURE

2.1 Inoculum preparation.

The preparation of inoculum media was carried out based on the modified methods of Gaind et al. (2009) and Irawan et al. (2023). The materials used in making this inoculum media are *Trichoderma* sp. isolate (Bio GGP 5) aged 7 days, 60g sorghum, 7.5 mL of 4% $CaSO_4$ solution, and 7.5 mL of 2% $CaCO_3$ solution. For the preparation of inoculum media, sorghum was put into a 250 mL sterile flat glass bottle, then sterilized in an autoclave. After the media cooled, then added $CaSO_4$ 4% and $CaCO_3$ 2% solution and inoculated as much as 1 ose of *Trichoderma* sp. isolate (Bio GGP 5), then incubated for 14 days or until spores appear.

2.2 POMEs composting

The composting is based on a modified Ustuner et al., (2009) method namely 1 : 1: 1 (POME sludge 4 kg, goat manure 4 kg and leaf litter 4 kg). Then, that mixure was added with *Trichoderma* sp. inoculum as much as 1 % of the total compost weight. The compost incubated for 3 weeks.

2.3 Peanut planting

Peanut were planted as many as 3 seeds per polybag with a depth of depth of ± 2 cm from the soil surface, after the plants were 1 week old, doing thinning. Thinning was done by uprooting 2 plants with poor growth and leaving 1 good plant for observation (Ramadani et al., 2015).

2.4 Applying compost and plant maintenance

The mature compost was then applied to groundnut plants using the modified Syofia and Daulay (2015) method with dose variations of 0%, 0.8%, 1.6%, 2.4%, 3.2%, 4.0%, and 4.8% in 5 kg of planting media (Andriyani et al., 2022) with the following details:

A0 : 100 % soil
A1 : 99,2 % soil + 0.8% compost
A2 : 98,4 % soil + 1,6 % compost
A3 : 97,6 % soil + 2,4 % compost
A4 : 96,8 % soil + 3,2 % compost
A5 : 96 % soil + 4,0 % compost
A6 : 95,2 % soil + 4,8 % compost

Plant maintenance is carried out by watering every day, weeding plants by pulling weeds that grow in polybags, and fertilizing compost every week until the plants are 4 weeks old.

2.5 Observations and statistical analysis

Observations on the growth of peanut plants included fresh and dry weight, shoot root ratio, fruit weight and chlorophyll content. Observations the parameters of fresh and dry weight, fruit weight, shoot root ratio, and chlorophyll content were observed after the plants were 4 weeks after planting. The data collected in the experiment were statistically analyzed with Statistical Program for Social Science (SPSS) software program. Analysis of variance (ANOVA) was done on every measured parameter to determine the significance of differences between means of treatments. Means for each parameter were separated by the least significant difference (LSD) test at $P \leq 0.05$.

III. RESULTS AND DISCUSSIONS

3.1 Fresh and dry weight

Based on the results of the LSD test that has been carried out and presented in Table 1, it shows that the application of POMEs compost induced by *Trichoderma* sp. (Bio GGP 5) has a significant effect on the fresh weight and dry weight peanut plants.

Table 1. Fresh weight and dry weight treated by induced POME compost of ligninolytic fungi inoculum

Treatments	Fresh Weight	Dry Weight
A0	27,83 ±0,38[b]	8,60 ±0,26[b]
A1	36,23 ±0,60[e]	16,23 ±0,58[e]
A2	**38,83 ±1,10[f]**	**19,83 ±0,97[f]**
A3	34,93 ±0,25[d]	16,23 ±0,25[d]
A4	28,17 ±0,30[b]	9,03 ±0,35[b]
A5	31,27 ±0,40[c]	11,27 ±0,45[c]
A6	24,73 ±0,85[a]	6,87 ±0,30[a]

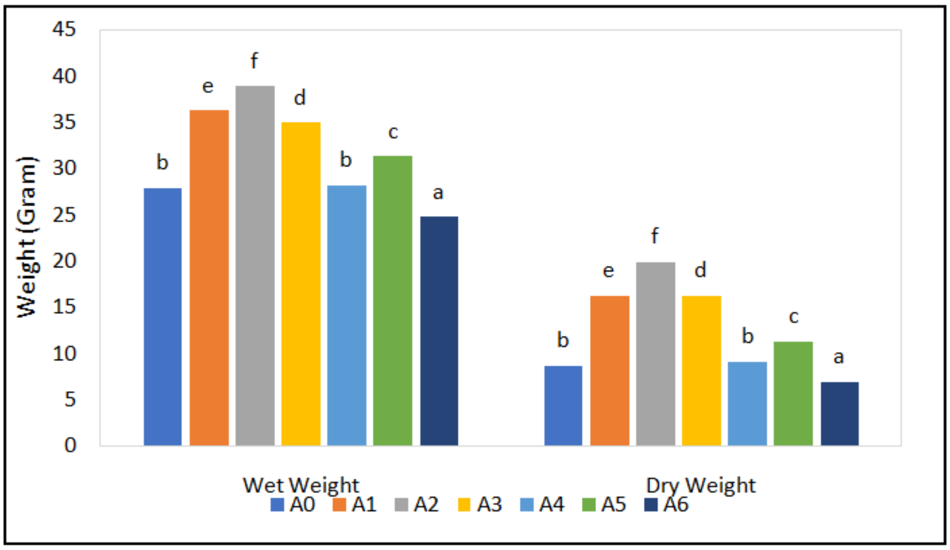
Description: Numbers followed by different letters within columns are signicantly different at P < 0,05

Figure 1 shows the effect of pome compost induced by *Trichoderma* sp. inoculum on peanut plants fresh weight and dry weight. The A2 treatment has the highest average fresh weight and dry weight, which is 38.83 g fresh weight and 19.83 g dry weight. Meanwhile the average fresh weight and the lowest dry weight were shown in the A6 treatment, which was 24.73 g fresh weight and 6.87 g dry weight.

Based on the LSD test results on fresh weight and dry weight parameters, it shows that the application of compost carried out in this research has a significant effect on the fresh weight and dry weight of peanut plants. This is in line with research conducted by Kartana et al. (2022) that palm oil solid waste can increase the growth and production of peanut plants, because it is rich in nutrients. The availability of nutrients plays an important role in the availability of nutrients plays an important role in affecting the biomass of a plant (Harjadi, 2007). Khasanah et al. (2020) also said that fertilizing POMEs compost on plants can provide additional organ volume in plants.

The average value of fresh weight and dry weight of peanut plants was highest in the A2 treatment (98.4% soil + 1.6% compost). The high fresh weight is related to the ability of plants to absorb water from the planting media, if the plants are more fertile and the number of leaves produced is increasing, then automatically the fresh weight of the plants will also increase (Wijayanti et al., 2019). The average value of fresh weight and dry weight of peanut plants was lowest in treatment A6 (95.2% soil + 4.8% compost). The low value of fresh weight and dry weight is thought to be due to excessive nutrient uptake that adversely affects the growth of peanut plants. This is in line with Morgan and Connolly (2013) that excess nutrients can be toxic to plants. When some nutrients accumulate very high in plants, the nutrients will form Reactive Oxygen Species (ROS) which can cause damage to plant cells. Some highly toxic elements such as lead cannot be distinguished from essential nutrients by the nutrient uptake system in plant roots, so toxic elements can enter plant tissues through the nutrient uptake system and result in reduced uptake of essential nutrients which can significantly inhibit growth and reduce plant quality.

Figure 1. Fresh and dry weight treated by induced POMEs compost of ligninolytic fungi inoculum



3.2 Root : Shoot Ratio

Based on the results of the LSD test that has been carried out and presented in Table 2, it shows that the application of POMEs compost induced by *Trichoderma* sp. (Bio GGP 5) has a significant effect on the fresh root shoot ratio and dry root shoot ratio of peanut plants.

Table 2. Fresh root shoot ratio and dry root shoot ratio treated by induced POME compost of ligninolytic fungi inoculum

Treatments	Root : Shoot Ratio					
	Fresh Weight			Dry Weight		
	Root	Shoot	Root Shoot Ratio	Root	Shoot	Root Shoot Ratio
A0	$0,97^{a}$	$3,63^{ab}$	$0,26^{a}$	$0,33^{ab}$	$1,80^{ab}$	$0,18^{ab}$
A1	$1,60^{c}$	$4,37^{e}$	$0,37^{cd}$	$0,53^{cd}$	$2,37^{cd}$	$0,22^{b}$
A2	**$1,80^{d}$**	**$4,63^{f}$**	**$0,39^{d}$**	**$0,63^{d}$**	**$2,57^{d}$**	**$0,25^{b}$**
A3	$1,53^{c}$	$4,27^{de}$	$0,36^{cd}$	$0,47^{bc}$	$2,27^{c}$	$0,20^{b}$
A4	$1,23^{b}$	$3,87^{bc}$	$0,32^{b}$	$0,40^{bc}$	$1,77^{a}$	$0,23^{b}$
A5	$1,40^{bc}$	$4,03^{cd}$	$0,35^{bc}$	$0,47^{bc}$	$2,00^{b}$	$0,23^{b}$
A6	$0,90^{a}$	$3,57^{a}$	$0,25^{a}$	$0,23^{a}$	$1,73^{a}$	$0,13^{a}$

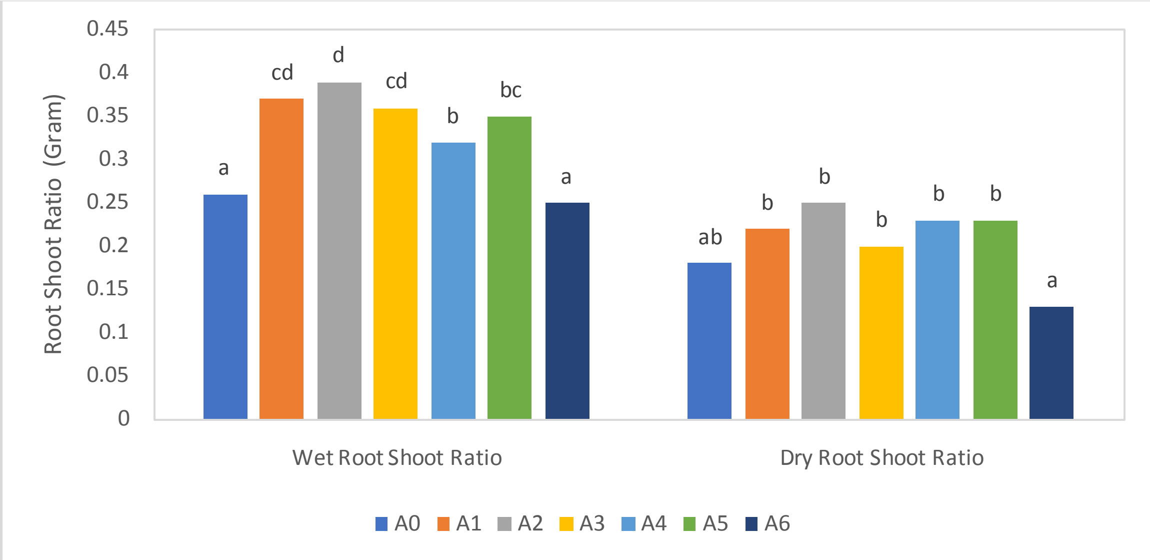
Description: Numbers followed by different letters within columns are signicantly different at $P < 0,05$

Based on Figure 2, The A2 treatment has the highest average root fresh weight and shoot fresh weight of peanut plant respectively 1,80 and 4.63 . Meanwhile, the highest average roots fresh weight and lowest shoot fresh weight were shown in A6 treatment which is 0,90 and 3,57 resepectively. In the calculation of dry weight of roots and shoots, treatment A2 produces the highest average value of root dry weight of 0,63 and shoot dry weight of 2,57 . The lowest average value is shown in treatment A6, which is 0,90 and 2,57 respectively. Meanwhile, the lowest average value was shown in treatment A6 with an average root dry weight of 0,23 and shoot dry weight of 1,73. Therefore, from these results, the highest fresh and dry root shoot ratio values were shown in the A2 treatment are 0,39 and 0,25.

Shoot-root ratio is a character that can be used as a marker of excess or deficiency of water and nutrients in plants. If the plant lacks the availability of nutrients and water, then root development becomes more dominant. Meanwhile, if the availability of nutrients and water for plants is optimal, then shoot growth will be more dominant (Wijayanto and Kardiyono, 2020). This is also in line with the opinion of Sulistyaningsih (2005) which states that excess water in plants will inhibit root growth compared to shoots.

Based on the LSD test results on the shoot root ratio parameter, treatment A2 (98.4% soil + 1.6% compost) showed the highest value of fresh shoot root ratio and dry shoot root ratio, but the root weight was smaller than the shoot weight. Meanwhile, the lowest average value of fresh and dry shoot root ratio was found in treatment A6 (95.2% soil + 4.8% compost). The shoot-root ratio value is influenced by shoot weight and root weight. The higher the value of plant weight and number of leaves will be accompanied by a higher value of shoot root ratio. This is in line with what Rusmana (2017) explained that the condition of the root crown ratio can show the effect of compost on plant growth. If the value of the shoot-root ratio is low, it can be concluded that the distribution of photosynthetic products towards the shoots is more than towards the roots, so that the proportion of root weight will be lower than the weight of the shoots.

Figure 2. Fresh root shoot ratio and dry root shoot ratio treated by induced POMEs compost of ligninolytic fungi inoculum



3.3 Chlorophyll Content

The results of research on the calculation of chlorophyll content in plants peanut plants that have been applied with POMEs compost induced by the inoculum of *Trichoderma* sp. is presented in Table 3.
Conflict of interest

Table 3. Chlorophyll content treated by induced POME compost of ligninolytic fungi inoculum.

Treatments	Chlorophyll Content		
	Chlorophyll a	Chlorophyll b	Chlorophyll Total
A0	1,12 ± 0,14^{a}	0,71 ± 0,08^{a}	1,83 ± 0,22^{ab}
A1	1,29 ± 0,08^{ab}	0,82 ± 0,05^{a}	2,11 ± 0,13^{ab}
A2	**1,42 ± 0,25^{ab}**	**0,58 ± 0,42^{a}**	**2,32 ± 0,42^{b}**
A3	1,19 ± 0,30^{ab}	0,74 ± 0,21^{a}	1,94 ± 0,52^{ab}
A4	1,09 ± 0,26^{ab}	0,67 ± 0,16^{a}	1,76 ± 0,42^{ab}
A5	0,94 ± 0,17^{ab}	0,56 ± 0,09^{a}	1,51 ± 0,26^{ab}
A6	1,17 ± 0,10^{b}	0,72 ± 0,06^{a}	1,89 ± 0,17^{ab}

Description: Numbers followed by different letters within columns are signicantly different at $P < 0,05$

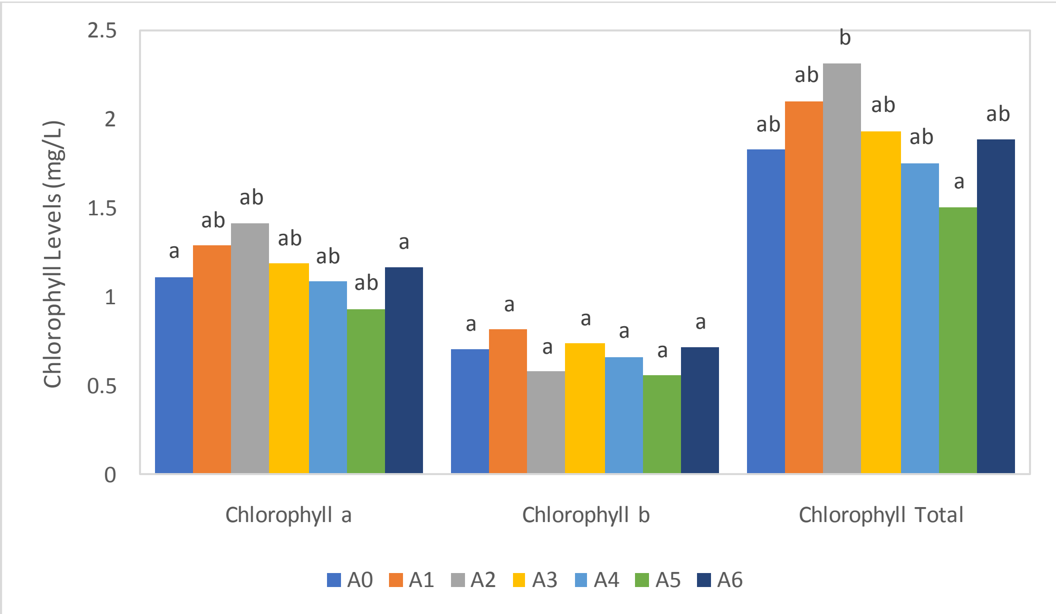
Based on the results of the LSD test that has been conducted and presented in Table 3, it shows that the application of POMEs compost induced by *Trichoderma* sp. (Bio GGP 5) gives a significant effect on the levels of chlorophyll a, chlorophyll b and total chlorophyll of peanut plants but not significantly different between each treatment. The A2 treatment had the highest average value in each observation, namely the average value obtained was chlorophyll a of 1.42 mg/L, chlorophyll b of 0.58 mg/L, and total chlorophyll of 2.32 mg/L. Meanwhile, the lowest value was shown in A5 treatment with an average chlorophyll a of 0.94 mg/L, chlorophyll b of 0.56 mg/L, and total chlorophyll of 1.51 mg/L.

Based on the calculation of chlorophyll a, chlorophyll b and total chlorophyll levels of peanut plants, it shows that the A2 treatment (98.4% soil + 1.6% compost) is the best compost dose that gives a real influence on the chlorophyll levels of peanut plants. Chlorophyll content is closely related to the number of plant leaves. This is related to the ability of the leaves to capture sunlight that occurs in the green leaves. Wider leaf morphology allows more optimal light capture and leaf thickness can also affect the value of chlorophyll formed (Manggas et al., 2021).

In the results of this research, the content of chlorophyll a has a higher average value compared to chlorophyll b. This shows that peanut plant leaves have the ability to capture light. This shows that the leaves of peanut plants have the ability to capture sunlight well, because chlorophyll a is a constituent of the reaction center in converting light energy into chemical energy which is later used in the photosynthesis process. The high level of chlorophyll in the leaves can be used as an indicator that a plant can carry out photosynthesis well. The rate of photosynthesis in plants is influenced by sunlight and leaf color. The greener the leaf color, the higher the chlorophyll content (Dharmadewi, 2020).

The low chlorophyll content in A5 treatment (96% soil + 4.0% compost) was probably influenced by the color of the leaves. The leaves produced from Treatment A5 had a light green color. Differences in the color of plant leaves can be influenced by the availability of nitrogen in the nutrients needed by plants. in the nutrients needed by plants. This is in accordance with what is stated by Tahoni et al., (2019) which states that the availability of nitrogen plays an important role in the formation of green plant leaves. Nitrogen is important in the formation of plant leaf green substances that are useful during the photosynthesis process. It can be concluded that the greener the leaf color, the higher the chlorophyll content. The main function of element N is chlorophyll synthesis. Chlorophyll functions to capture sunlight which will be used in the formation of In the process of photosynthesis, the chlorophyll content will help and spur plant growth, especially stimulating plant vegetative organs.

Figure 3. Fresh root shoot ratio and dry root shoot ratio treated by induced POMEs compost of ligninolytic fungi inoculum



3.4 Fruit Weight

Based on the results of the LSD test that has been carried out and presented in Table 6, it shows that the application of POMEs compost induced by *Trichoderma* sp. (Bio GGP 5) has a significant effect on the fruit weight of peanut plants.

Table 4. Fruit weight treated by induced POMEs compost of ligninolytic fungi inoculum.

Treatments	Fruit Weight
A0	13,47 ±0,76^{ab}
A1	15,47 ±0,55^{bc}
A2	**16,20 ±0,98^{d}**
A3	15,17 ±0,38^{cd}
A4	14,63 ±0,30^{bc}
A5	13,63 ±0,75^{ab}
A6	13,10 ±0,56^{a}

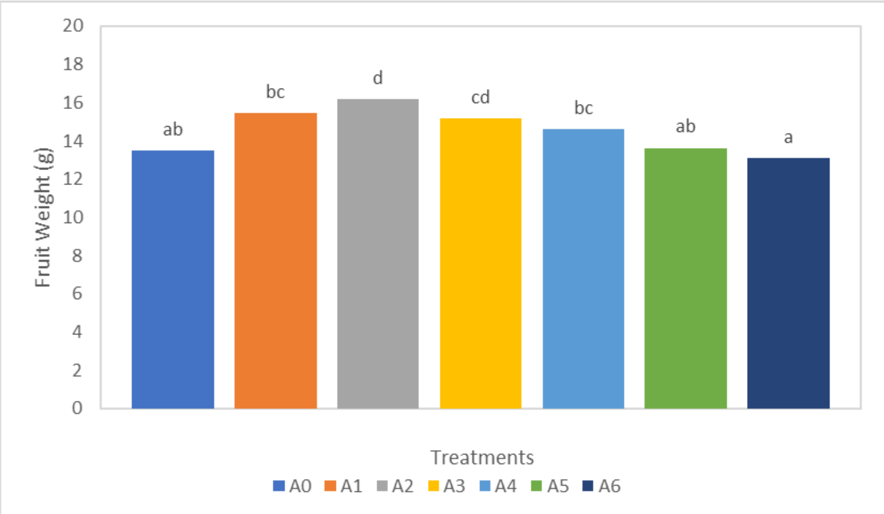
Description: Numbers followed by different letters within columns are signicantly different at P < 0,05

Based on Figure 4, The highest average fruit weight on the A2 treatment which is 16.2 g. Meanwhile the lowest value was shown in the A6 treatment with an average of 13,10 g. This shows that the application of POME compost at a dose of 1.6 % compost + 98,6 % soil has a significant effect on the fruit weight of peanut plants.

The high average weight of peanut fruit in the A2 treatment is thought to be due to the dose of POME compost induced by Trichoderma sp. fungus which is able to increase nutrients that are beneficial for plant fertility. This is in line with what Adi et al. (2020) stated that the availability of nutrients in the planting media has a significant influence on vegetative growth and generative growth of plants. Not only that, Sakiah and Wahyuni (2018) said that POMEs also contains many organic compounds including Nitrogen, Phosphorus, and potassium. Nitrogen is useful in accelerating vegetative growth, Phosphorus is useful in increasing the quality of fruit weight and Potassium accelerates the reaction of photosynthesis rate and translocation in increasing fruit weight (Nursayuti, 2019).

The low average weight of peanut fruit in treatment A6 (95.2% soil + 4.8% compost) is thought to be due to the absorption of excess nutrients from the compost given, so that the development of peanut fruit weight does not take place optimally. This is in accordance with what is stated by Nurhayati (2021) that excess nutrients will have a negative impact on generative growthmof plants. Too much nitrogen, phosphorus and potassium can make the plants too fertile, so the plants do not have a sturdy structure, so they can easily collapse. In addition, flower and fruit production may decrease and plants become susceptible to disease.

Figure 4. Fruit weight treated treated by induced POMEs compost of ligninolytic fungi inoculum



Conflict of interest

There is no conflict to disclose.

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