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Research Article
Effect of Dried Decanter Solid and Arbuscular Mycorrhizal Fungi on Growth and Production of Mung Bean in Acid Lands

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Abstract
Background and Objective: Mung bean is one of the most important food legume crops in Indonesia which contains balanced nutrients. Increasing mung bean productivity is currently directed at sub-optimal lands due to limited fertile land, including acid land. Optimization of growth and production of mung beans in acid land can be done by providing organic matter. The study aims to identify the effect of dried decanter solid (DDS) and arbuscular mycorrhizal fungi (AMF) application on the growth and production of mung bean plants in acid lands. **Materials and Methods:** This research was conducted at Kopertis Growth Center Region I, Deli Serdang Regency, North Sumatra Province, Indonesia. This research was conducted using a factorial randomized block design (RBD), with two factors. The first factor is dried decanter solid consisting of 4 levels, namely 0, 150, 300 and 450 g/polybag. The second factor is arbuscular mycorrhizal fungi consisting of 4 levels, namely 0, 6, 12 and 18 g/polybag. **Results:** The application of dried decanter solid 300 g/polybag significantly increased plant height, the number of branches and seed weight per plot, besides the application of dried decanter solid 450 g/polybag significantly increased root length. **Conclusion:** Dried decanter solids can be used to optimize the growth and production of mung bean in acid lands.

Key words: Legume, decanter solid, mycorrhizal, organic matter, yield, acid-dry land

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Mung bean is one of the legume crops that is broadly consumed by Indonesian people. The balanced nutrition contained in mung bean is protein, minerals, vitamins, dietary fiber and bioactive compounds[1]. In addition, mung bean also contains calcium, iron, sulfur, manganese, magnesium, niacin and fatty oils. Due to its high protein content and hypoallergenic properties, several studies have recommended mung bean as a supplement for preparing an infant's weaning[2,3]. Another benefit of this plant is that it can be used to treat hyperglycemia, hyperlipemia and hypertension as well as prevent cancer and melanogenesis[4].

The demand for mung beans from year to year is increasing, exceeding the total national production. The average need for mung beans every year is 330,000 tons. In 2012, a land area of 24,500,600 ha produced only a national average of 284,257 tons of mung beans with a productivity of around 0.116 tons ha^{-1}. Based on the data above, the productivity of mung beans is still relatively low, because the productivity of mung beans is optimally 2.5-2.8 tons ha^{-1} in a good environment and cultivation techniques, causing the development of mung bean imports from 2002-2012 to increase by 16.53% with an average annual import volume of 29,443 tons[5].

The narrower fertile agricultural land, which is widely used for settlements, offices and other public facilities, needs efforts to increase food production, including by utilizing acid-dry land[6]. In acid-dry land characterized by pH<5 and generally has a level of soil fertility providing organic material can increase the content of organic matter in the soil and to achieve optimal productivity high input is needed[7].

Indonesia has quite a large marginal land area, including acid-dry land with an area of ±102.8 million hectares. Acid-dry land is 67.5% of the total area of agricultural land spread outside Java, including Kalimantan, Sumatra, Sulawesi and Papua. Acid-dry lands in Java include Grobogan, Banyuwangi, Cisarua, Mojokerto and Bantul areas[8]. However, there are several obstacles in acid soil. According to Retnowati and Surahman[9] said that dry land is classified as a suboptimal soil type for farming because it is less fertile, reacts sourly and contains high amounts of Al, Fe, or Mn which can poison plants. Acidic soils are also generally poor in organic matter and macronutrients, such as N, P, K, Ca and Mg. Soil acidification impact as well as pH level has been seriously recorded on agricultural soil. The substitution of exchangeable base cations as potassium (K^+), calcium (Ca^{2+}) and magnesium (Mg^{2+}) by Al^{3+} and H^+ (pH at 5-6) and the dissolution of Al-bearing and Mn minerals (pH at 4) and the dissolution of Fe-bearing minerals are the most significant consequences of soil acidifications with buffer the soil pH at 3[10]. Hence, in acid soils occurs toxicity of metal (Al, Fe, Mn) and imbalance of nutrients (P)[11].

Improvement of the physical and chemical properties of soil can be carried out, including by adding organic matter which has an important role in determining the ability of the soil to support plants, so that if the soil's organic matter content decreases, the ability of the soil to support plant productivity also decreases[12]. Decreasing levels of organic matter is a common form of soil damage. Soil organic matter (SOM) affects the chemical, physical and biological properties of the soil. The high SOM content increases the nutrient supply and soil buffering capacity[13,14]. Increasing the SOM content contributes also to the higher C sequestration in the soil[15]. Consequently, the loss of topsoil by erosion is minimized. Therefore, the maintenance or increase of the SOM content is particularly important for maintaining the productivity of the agroecosystems.

The organic matters used in this study were dried decanter solid (DDS) and arbuscular mycorrhizal fungi (AMF). Solid decanter is palm oil mill solid waste. Solids come from mesocarp or palm kernel fiber, which has undergone processing at palm oil mill (POM). Solid is the final product in the form of solids from the fresh fruit bunches (FFB) processing process in POM using a decanter system. A decanter is used to separate the liquid phase (oil and water) from the solid phase to the last particles. The decanter can remove 90% of all solids from palm sludge and 20% of dissolved solids from palm oil[16]. Besides, arbuscular mycorrhizal fungi (AMF) is a Glomeromycetes fungus that is known to be able to help increase the productivity of forage. The utilization of AMF contributes to the availability of P nutrients in acid soils[17]. The research result of Tarigan *et al.*[18] reported that the application of mycorrhizal biofertilizer 9 g/plant can increase the plant height, wet weight and dry weight of cacao seedlings. The combination of AMF species, host plant species and P nutrient sources are known to affect the effectiveness of AMF in increasing forage productivity[19].

Based on the above, it is necessary to conduct research on the application of dried decanter solid (DDS) and arbuscular mycorrhizal fungi (AMF) in an effort to optimize the growth and production of mung bean plants in acid lands.

MATERIALS AND METHODS

Study area: This research was conducted at Kopertis Growth Center Region I Jl. Peratun 1, Percut Sei Tuan, Deli Serdang Regency, North Sumatra Province, Indonesia with an altitude of ± 27 masl, in November, 2018 to January, 2019.

Materials: The materials used were 192 mung bean seeds of the Vima-2 variety, dried decanter solid, arbuscular mycorrhizal fungi, acid soil, water, polybags 30x35 cm, insecticide Prevathon 50 Suspension Concentrate (active ingredient: Chlorantraniliprole), insecticide Decis 25 Emulsion Concentrate (active ingredient Deltamethrin) and other supporting materials.

Study design: This research was conducted using a factorial randomized block design (RBD), with two factors. The first factor is dried decanter solid (DDS) consisting of 4 levels, namely S_0 = 0 g/polybag, S_1 = 150 g/polybag, S_2 = 300 g/polybag and S_3 = 450 g/polybag. The second factor is arbuscular mycorrhizal fungi (AMF) consisting of 4 levels, namely M_0 = 0 g/polybag, M_1 = 6 g/polybag, M_2= 12 g/polybag and M_3= 18 g/polybag.

Application of dried decanter solid: Dried decanter solid (DDS) is obtained from the Palm Oil Mill of Socfin Indonesia Ltd. A dried decanter solid was applied 2 weeks before the seeds were planted. The dried decanter solid was applied by mixing it with polybag soil according to the level of treatment.

Application of arbuscular mycorrhizal fungi: Arbuscular mycorrhizal fungi (AMF) were obtained from the Laboratory of the University of North Sumatra, Medan. The application of arbuscular mycorrhizal fungi is carried out when planting mung bean seeds. Arbuscular mycorrhizal fungi were applied by inserting them into the planting hole with a depth of ±2 cm according to the level of treatment.

Statistical analysis: The research data were analyzed using Analysis of Variance (ANOVA) and continued with Duncan's Multiple Range Test (DMRT) at 5%.

RESULTS AND DISCUSSION

Plant height: Based on the results of statistical analysis showed that the application of dried decanter solid had a significant effect on plant height. Meanwhile, the application of arbuscular mycorrhizal fungi and the interaction of the two treatments did not significantly affect plant height. The mean of plant height can be seen in Table 1.

The application of dried decanter solid at 2 week after planting (WAP) did not have a significant effect, while at 3, 4 and 5 (WAP) it had a significant effect with the highest mean of plant height in the S_0, namely 14.46, 19.13 and 31.43, respectively, but at 6 WAP did not have a significant effect again. This is presumably because the availability of nutrients in acidic soil is not optimal so it affects plant height growth. Human activities that result in the formation of acid soils such as construction and mining will cause plant death[20]. Wilting in plants is caused by low soil pH and the dissolution of toxic elements (Al, Fe and Mn) in acidic conditions. The inhibition of root growth is one of the main consequences and the most obvious symptom of Al toxicity[21]. Excess Al will inhibit root cell division-elongation and formation of root hairs and promote the development of swollen root apex. Simultaneously, toxic Al inhibits water and nutrient uptakes[11].

Number of branches: Based on the results of statistical analysis showed that the application of solid dried decanter had a significant effect on the number of branches. While the application of arbuscular mycorrhizal fungi and the interaction of the two treatments did not significantly affect the number of branches. The mean number of branches can be seen in Table 2.

Application of dried decanter solid showed the number of branches with the highest means at 2 WAP with S_0 is 1.67, which was significantly different from S_1 (1.19 branches), S_2 (1.11 branches) and S_3 (1.08 branches). At 4 WAP, the highest mean number of branches was found in the S_0 namely 5.61, which was significantly different from the S_1 (4.78 branches), S_2 (4.81 branches) and S_3 (4.69 branches), while in 6 WAP the highest mean was in the S_2, namely 11.75 branches which are significantly different from S_0 (10.28 branches) but not significantly different from the S_1 (11.28 branches) and S_3 (11.25 branches).

The relationship between the number of branches of the mung bean plant at 6 WAP with dried decanter solid application can be seen in Fig. 1.

The application of dried decanter solid with the optimum dose of 300 g/polybag can increase the number of branches by a mean of 11.75 and shows a quadratic relationship with the determination equation $\hat{y} = 10.25+0.009x-0.05x^2$, the value of r^2 = 0.991 as shown in Fig. 1. It is suspected that the application of dried decanter solid at a dose of 300 g/polybag is appropriate for plant growth so that it affects the growth of the number of plant branches. The type of agricultural management applied influences soil properties, both positively and negatively[22,23]. Therefore, proper agricultural practices and soil management can result in soil property improvements such as organic carbon content increases, soil structure recovery and infiltration rate improvement[24]. In addition, it can also increase bulk density, porosity, soil water content, distribution of nutrients and stability of soil

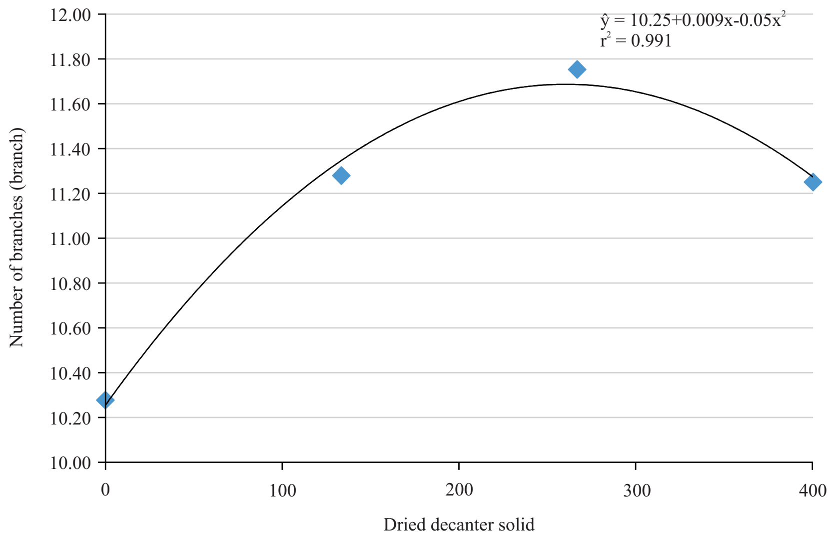

Fig. 1: Graph of the number of branches at 6 WAP to the application of dried decanter solid

Table 1: Plant height of mung bean with dried decanter solid application at 2, 3, 4, 5 and 6 week after planting (WAP)

	Observation time (week after planting) cm				
Dried decanter solid	2	3	4	5	6
S_0	11.06	14.46^a	19.13^a	31.43^a	42.46
S_1	11.15	13.30^b	16.31^b	25.86^b	42.46
S_2	10.99	13.20^b	16.14^b	25.53^b	43.60
S_3	10.90	12.83^b	15.96^b	25.67^b	42.95

Numbers followed by different letters in the same column are significantly different according to DMRT at 5%

Table 2: Number of branches with solid dried decanter application at 2, 4 and 6 Week after planting (WAP)

	Observation time (week after planting) Branch		
Dried decanter solid	2	4	6
S_0	1.67^a	5.61^a	10.28^b
S_1	1.19^b	4.78^b	11.28^a
S_2	1.11^b	4.81^b	11.75^a
S_3	1.08^b	4.69^b	11.25^a

Numbers followed by different letters in the same column are significantly different according to DMRT at 5%

structures. Furthermore, cropping patterns and soil management can change the soil properties, nutrient levels, organic carbon content and soil organisms living conditions, so affecting the biological processes majority[24-28].

Flowering age: Based on the results of statistical analysis, shows that the application of solid dried decanter has a significant effect on flowering age. While the application of arbuscular mycorrhizal fungi and the interaction of the two treatments had no significant effect on flowering age. The mean flowering age can be seen in Table 3.

Based on Table 3, it can be seen that the highest mean age of flowering with dried decanter solid application was found in S_1, S_2 and S_3, namely 34.50, which was significantly different from the S_0, namely 33.67, while the highest mean with the arbuscular mycorrhizal fungi application was in M_3, namely 34 .50 and the lowest mean in M_2, namely 34.00.

The relationship between the flowering age of mung bean plants and dried decanter solid application can be seen in Fig. 2.

Figure 2 showed the relationship between the application of solid dried decanter to the flowering age, which is positive

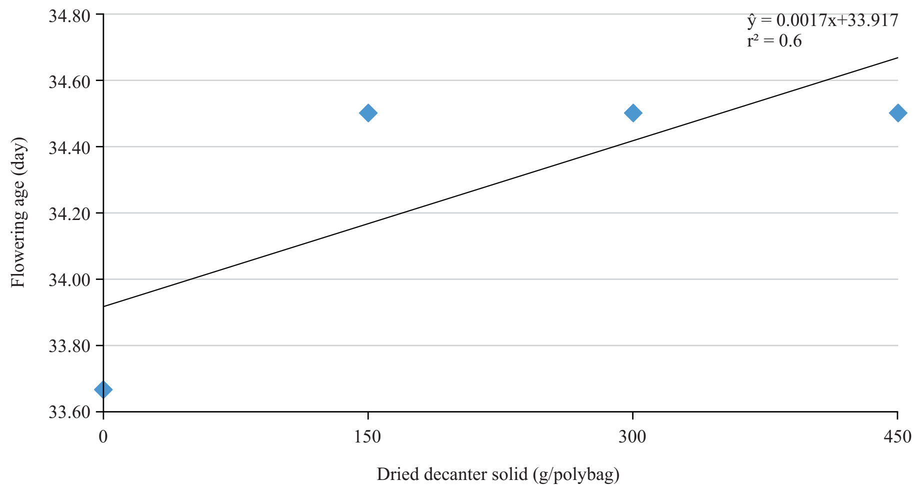

Fig. 2: Graph of flowering age with dried decanter solid applications

Table 3: Flowering age of mung bean with the application of dried solid decanter and arbuscular mycorrhizal fungi

	Arbuscular mycorrhizal fungi				
	Day				
Dread decanter solid	M_0	M_1	M_2	M_3	Mean
S_0	34.33	33.00	33.33	34.00	33.67[b]
S_1	34.67	34.33	33.67	35.33	34.50[a]
S_2	34.33	35.33	34.67	33.67	34.50[a]
S_3	34.33	34.33	34.33	35.00	34.50[a]
Mean	34.42	34.25	34.00	34.50	34.29

Numbers followed by different letters in the same column are significantly different according to DMRT at 5%

linear with the regression equation $\hat{y}$ = 33.91+0.001x, the value of r^2 = 0.6. Based on the graph, it can be seen that without the administration of dried decanter solid, it shows an earlier flowering age compared to the application of dried decanter solid. It is suspected that the weathering process of the dried decanter solid is imperfect so the availability of nutrients from the solid cannot be absorbed by plants. The decomposition of organic matter is largely a biological process that occurs naturally. Its speed is determined by three major factors: soil organisms, the physical environment and the quality of the organic matter. In the decomposition process, different products are released: Carbon dioxide (CO_2), energy, water, plant nutrients and resynthesized organic carbon compounds[29].

Total chlorophyll: Based on the results of statistical analysis, showed that the application of dried decanter solid had a significant effect on total chlorophyll. While the application of arbuscular mycorrhizal fungi and the interaction of the two treatments did not significantly affect total chlorophyll. The mean of total chlorophyll can be seen in Table 4.

Based on Table 4, it can be seen that the amount of chlorophyll with the highest mean application of dried decanter solid was found in S_0, namely 52.45 mL g^{-1}, significantly different from S_1 (47.45 mL g^{-1}), S_2 (47.39 mL g^{-1}) and S_3 (47.67 mL g^{-1}). While the highest mean of arbuscular mycorrhizal fungi applications was found in M_3 namely 49.50 mL g^{-1} and the lowest mean in M_2 namely 47.91 mL g^{-1}.

The relationship between the chlorophyll total in mung bean leaves and the dried decanter solid application can be seen in Fig. 3.

Figure 3 showed the relationship between the application of dried decanter solid to the chlorophyll total of the leaf that is quadratic with the determination equation $\hat{y}$ = 52.22-0.036x+0.000005x^2, the value of r^2 = 0.942. Based on the graph, it can be seen that the highest amount of chlorophyll was in the S_0, namely 52.45 mL g^{-1}. This is presumably without the addition of solid dried decanter which has sufficient nitrogen content to make the plant leaves greener. This is in accordance with Fathi[30] who states that nitrogen functions to accelerate plant growth, make plant leaves greener and fresher and contain lots of green leaf grains that play an

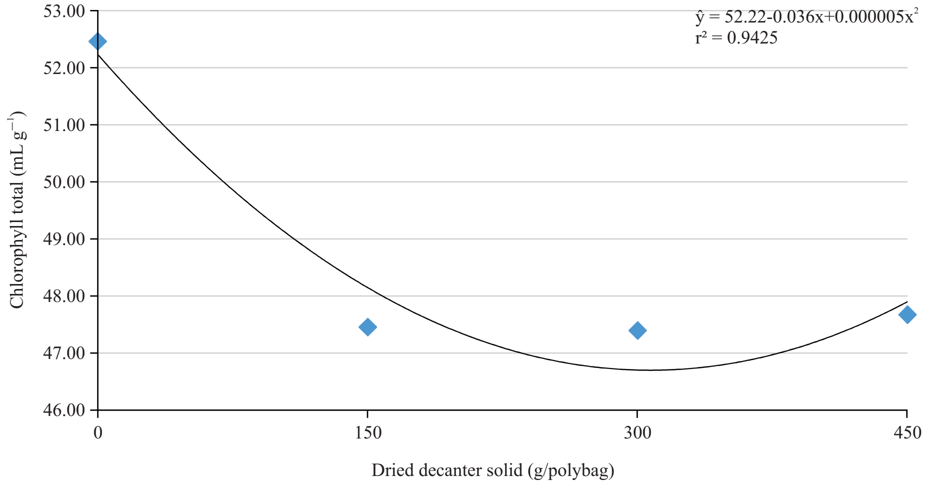

Fig. 3: Graph of chlorophyll total with dried decanter solid applications

Table 4: Total of chlorophyll in mung bean leaves with the application of dried solid decanter and arbuscular mycorrhizal fungi

	Arbuscular mycorrhizal fungi (mL g^{-1})				
Dread decanter solid	M_0	M_1	M_2	M_3	Mean
S_0	52.94	51.31	50.80	54.75	52.45^a
S_1	47.28	47.14	48.56	46.84	47.45^b
S_2	49.81	46.88	44.48	48.40	47.39^b
S_3	47.08	47.82	47.79	47.99	47.67^b
Mean	49.28	48.29	47.91	49.50	48.74

Numbers followed by different letters in the same column are significantly different according to DMRT at 5%

important role in the process of photosynthesis. In addition, nitrogen has the function to increase the protein content in plants.

Seed weight per plant, seed weight per plot and weight of 100 seeds: Based on the results of statistical analysis, it was shown that the application of dried decanter solid had a significant effect on seed weight per plant, seed weight per plot and weight of 100 seeds. While the application of arbuscular mycorrhizal fungi and the interaction of the two treatments had no significant effect on seed weight per plant, seed weight per plot and weight of 100 seeds (Table 5).

Based on Table 5, it can be seen that the application of dried decanter solid had a significant effect on seed weight per plant sampled at 55, 62 and 77 DAP. Application of dried decanter solid, the highest seed weight per plant at 55 DAP was found in S_0 namely 9.44 g which was significantly different from S_1 (6.62 g), S_2 (6.90 g) and S_3 (6.83 g), while the highest mean at 62 DAP was in S_2, namely 9.91 g, which was significantly different from the S_0, namely 6.19 g, but not significantly different from the S_1 (9.36 g) and S_3 (8.52 g), while the highest mean was at 77 DAP was found in S_0 namely 9.58 g which was significantly different from the S_1 (7.74 g) and S_2 (5.62 g) but not significantly different from the S_3 namely 7.67 g.

The relationship between seed weight per plant of mung bean at 77 DAP with the application of dried decanter solid can be seen in Fig. 4.

Figure 4 showed the relationship of dried decanter solid application to seed weight per plant, namely quadratic with the determination equation $\hat{y} = 9.798-0.024x+0.0005x^2$ value of $r^2 = 0.873$. Based on the graph, it can be seen that the highest number of seed weights per sample plant was found in S_0, namely 9.58 g. This is presumably without dried decanter solid having sufficient phosphorus content so that it affects seed weight per sample plant, on the other hand, phosphorus also affects plant root growth so that it has a positive correlation with the growth of all plants. This was in accordance with the opinion of Samosir and Lahay[31] which stated that phosphorus (P) is important for accelerating root growth, accelerating plant maturity, accelerating fruit and seed formation and increasing production. Sources of

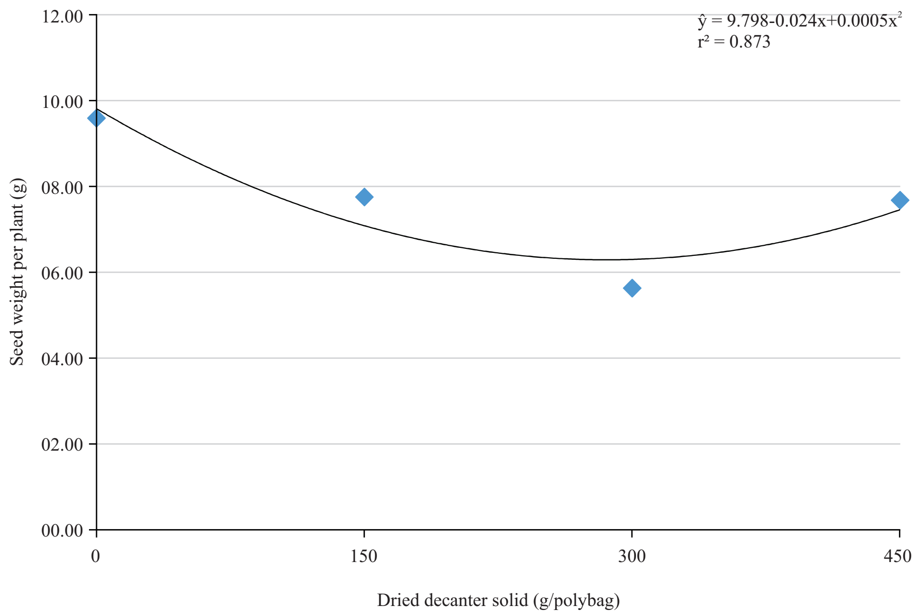

Fig. 4: Graph of seed weight per plant with dried decanter solid applications

Table 5: Seed weight per plant, seed weight per plot and weight of 100 seeds with dried decanter solid applications at 55, 62 and 77 day after planting (DAP)

	Observation time (day after planting)								
	55			62			77		
Dried decanter solid	Seed weight per plant (g)	Seed weight per plot (g)	Weight of 100 seed (g)	Seed weight per plant (g)	Seed weight per plot (g)	Weight of 100 seed (g)	Seed weight per plant (g)	Seed weight per plot (g)	Weight of 100 seed (g)
S_0	9.44[a]	37.34[a]	7.75	6.19[b]	25.55[b]	8.27[a]	9.58[a]	37.23[a]	7.88
S_1	6.62[b]	26.40[b]	7.75	9.36[a]	36.44[a]	7.63[b]	7.74[b]	28.16[b]	8.11
S_2	6.90[b]	27.35[b]	7.63	9.91[a]	41.24[a]	7.30[b]	5.62[b]	21.34[b]	7.43
S_3	6.83[b]	25.84[b]	7.64	8.52[a]	33.45[ab]	7.76[ab]	7.67[ab]	27.07[b]	7.62

Numbers followed by different letters in the same column are significantly different according to DMRT at 5%

phosphate in the soil as mineral phosphate, namely phosphate limestone, plant residues and other organic matter and artificial fertilizers (double phosphate, super phosphate and others). The absorption and conversion of organic phosphorus into inorganic phosphorus are carried out by microorganisms.

Table 5 also showed that the application of solid dried decanter had a significant effect on seed weight per plot at 55, 62 and 77 DAP. In the application of dried decanter solid, it can be seen that the highest mean of seed weight per plot at 55 DAP was found in S_0, namely 37.34 g, which was significantly different from the S_1 (26.40 g), S_2 (27.35 g) and S_3 (25.84 g), while the highest mean at 62 DAP was found in S_2, which was 41.24 g, which was significantly different from the S_0 namely 25.55 g, but not significantly different from the S_1 (36.44 g) and S_3 (33.45 g). while the highest mean at 77 DAP was found in S_0 namely 37.23 g which was significantly different from S_1 (28.16 g), S_2 (21.34 g) and S_3 (27.07 g).

The relationship between seed weight per plot of mung bean at 77 DAP and the application of dried decanter solid can be seen in Fig. 5.

Figure 5 showed the relationship of the application of dried decanter solid to seed weight per plot, namely quadratic with the determination equation $\hat{y}$ = 37.74-0.098x+0.000x^2, the value of r^2 = 0.959. Based on the graph, it can be seen that the highest number of seed weights per plot in S_0, namely 37.23 g. It is suspected that the availability of nutrients without the provision of the solid dried decanter is available compared to the provision of the solid-dried decanter, in general, organic matter undergoes a decomposition process so that it can be utilized by plants. One of the obstacles to the decomposition process of organic matter is c-organic. According to Li *et al.*[32], the relationship between c-organic and total nitrogen in the soil is very important. The availability of c-organic as an energy source, if its availability is excessive, it will inhibit the

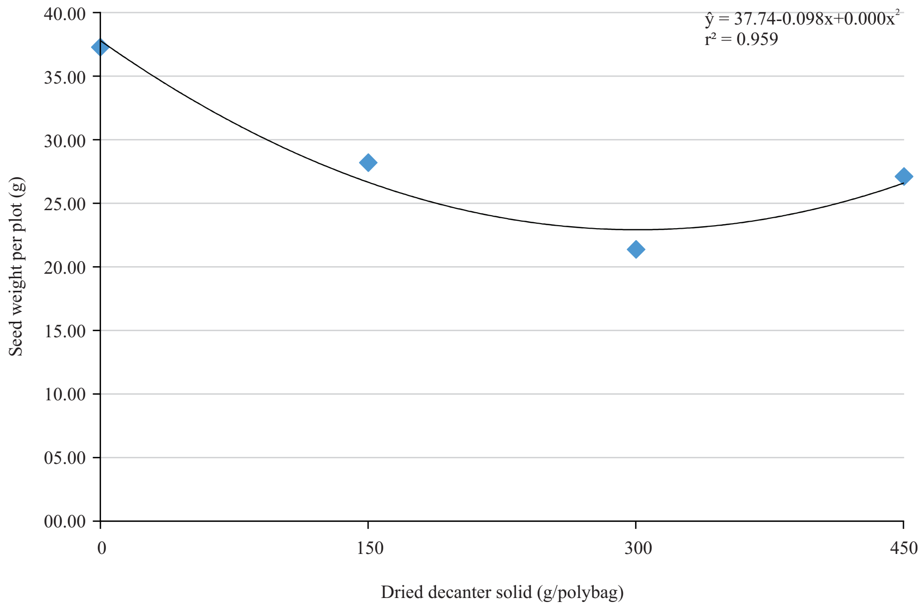

Fig. 5: Graph of seed weight per plot with dried decanter solid applications

development of microorganisms, due to the excessive increase in c-organic compared to the total nitrogen content in the soil. As a result, an increase in c-organic will inhibit the formation of proteins, which will inhibit the activities of microorganisms. Therefore, the c-organic and total N-content in the soil is used to determine the level of weathering and the rate of decomposition of organic matter and the availability of nutrients in the soil.

The application of dried decanter solid had a significant effect on the weight of 100 seeds at 62 DAP. The dried decanter solid application showed that the highest mean weight of 100 seeds at 55 DAP was found in S_0 and S_1, namely 7.75 g and the lowest in S_2, namely 7.63 g, while the highest mean was at 62 DAP, in S_0, namely 8.27 g which was significantly different from S_1 namely 7.63 g and S_2 namely 7.30 g but not significantly different from the S_3 which was 7.76 g, while the highest mean at 77 DAP was found in S_1 namely 8.11 g and the smallest in S_2 namely 7.43 g. This was presumably due to the minimum availability of nitrogen elements when filling the seeds which has an impact on the leaves turning yellow it affects the results of the seed-filling process. According to Sehgal *et al.*[33], an increase in N translocation to seeds during seed filling causes an acceleration of leaf aging so that the seed filling period becomes shorter and consequently the yield will decrease. To slow down leaf senescence, it is necessary to add N when the plants start to flower, which also increases the supply of N when filling the seeds.

Figure 6 showed an increase in production from the first harvest at 55 DAP to the second harvest at 62 DAP, namely 1403.08 to 1640.16 g, but there was a decrease in yield in the third harvest at 77 DAP, namely 1365.53. A decrease in crop yields can occur due to physiological changes in plants such as yellowing leaves that interfere with leaf function which is bad for plants. Yellowing of leaves is a genetically regulated form of leaf senescence[34]. Several factors cause yellowing of leaves including age, pathogens, harvesting, mechanical damage and environmental stresses[35].

Root length: Based on the results of statistical analysis, shows that the application of dried decanter solid has a significant effect on root length. While the application of arbuscular mycorrhizal fungi and the interaction of the two treatments did not significantly affect root length. The mean of root length can be seen in Table 6.

Based on Table 6 it can be seen that the highest mean of root length with the dried decanter solid application was found in S_3, namely 45.50 cm which was significantly different from S_0 (32.58 cm) but not significantly different from S_1 (42.08 cm) and S_2 (44.00 cm), while the highest mean in the application of arbuscular mycorrhizal fungi was in M_3 namely 45.42 cm and the lowest mean in M_1, namely 37.08 cm.

The relationship between the root length of the mung bean plant and the application of dried decanter solid can be seen in Fig. 7.

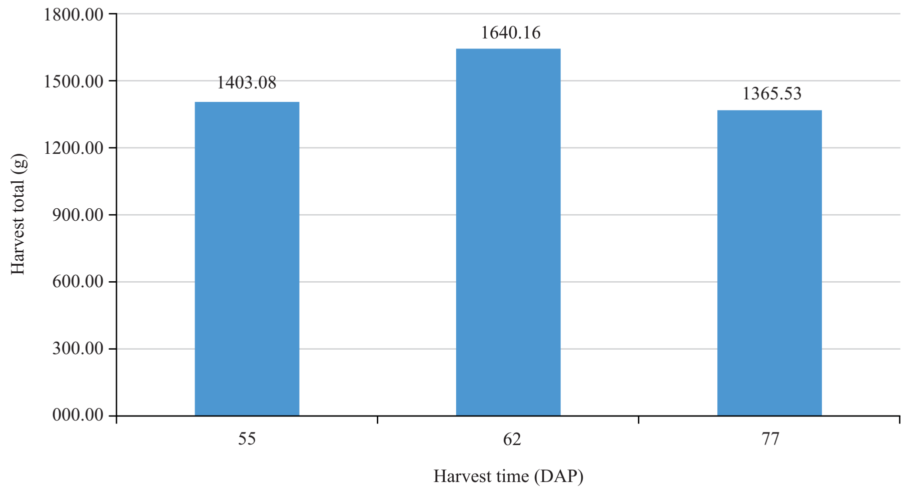

Fig. 6: Histogram of total harvest with the application of solid dried decanter and arbuscular mycorrhizal fungi

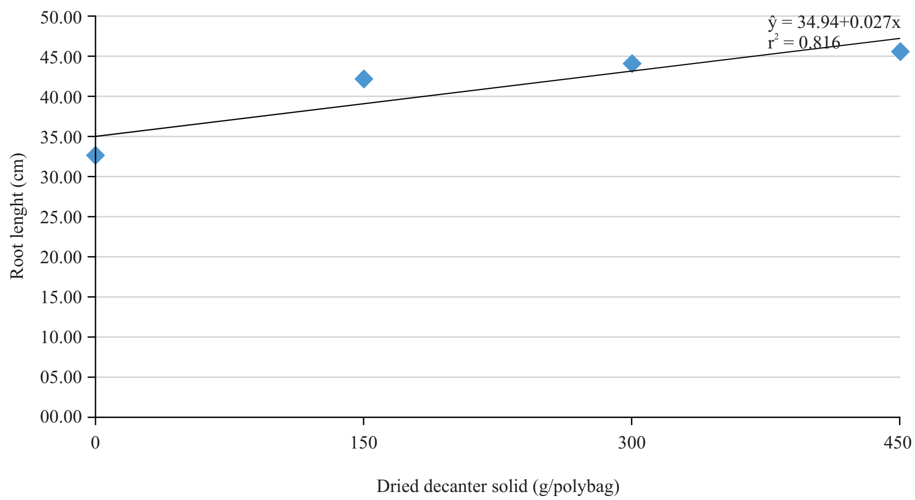

Fig. 7: Graph of root length with dried decanter solid applications

Table 6: Root length of mung bean with the application of dried solid decanter and arbuscular mycorrhizal fungi

	Arbuscular mycorrhizal fungi				
	cm				
Dread decanter solid	M_0	M_1	M_2	M_3	Mean
S_0	29.67	29.33	40.00	31.33	32.58^b
S_1	42.00	41.33	41.00	44.00	42.08^a
S_2	43.67	40.00	44.00	48.33	44.00^a
S_3	41.67	37.67	44.67	58.00	45.50^a
Mean	39.25	37.08	42.42	45.42	41.04

Numbers followed by different letters in the same column are significantly different according to DMRT at 5%

Figure 7 showed the relationship between the application of dried decanter solid on root length, which is positive linear with the regression equation $\hat{y} = 34.94+0.027x$, the value of $r^2 = 0.816$. Based on the graph, it can be seen that the longest root length is in the S_3, which was 45.50 cm. It was suspected that the application of dried decanter solid is able to improve soil porosity so that the loose soil structure can facilitate the development of roots in the soil, on the other hand, dried decanter solid is also able to store water so that the availability of water is always sufficient for plant growth. Plant root systems greatly impact the soil and there is a functional link between root density, soil depth and soil properties. Plant root systems may intensify the hydrological and ecological function of rainfall regulation, storage and infiltration by increasing soil porosity, non-capillary porosity and field capacity[36]. In addition, factors influencing soil's total and non-capillary porosity are organic matter, structure and soil arrangement, cultivation, fertilization and rainfall[37]. Furthermore, the external impact has a significant effect on the root system. The distribution of soil moisture is one of the key factors to guide the root system[38]. According to Jin *et al.*[39], the root system will grow optimally in soil conditions that are both physical and chemical. The root system has a positive correlation with the resulting growth. Long plant roots will increase the ability to absorb water and nutrients so as to produce optimal growth in plant height, number of leaves and number of stalks.

In principle, plants are the same as humans who need nutrients for their growth and development. Plant food substances are in the form of simple elements called nutrients, namely chemical elements needed by plants to carry out physiological processes so that plant life takes place properly, both under optimum conditions and under stress. The application of dried decanter solid (DDS) is useful in adding soil nutrients because it contains nutrients such as N, P, K and Mg which are needed for plant growth and development processes. In addition, the rate of uptake of nutrients by the plant root system depends on the speed at which plant roots reach nutrients, where the movement of nutrients in the soil is influenced by many factors. These factors include soil factors (moisture, buffering capacity, temperature) and plant factors (root length, root density and root infection) by arbuscular mycorrhizal fungi. Mycorrhiza is a symbiotic association between fungi and plants that colonizes the root cortex tissue of plants, occurring during the active growth period of the plant. Plant growth is increased in the presence of mycorrhiza due to increased nutrient uptake, resistance to drought, production of growth hormones and growth regulators, protection from root pathogens and toxic elements.

The results of this study indicated that the application of dry decanter solid (DDS) and arbuscular mycorrhizal fungi (FMA) is proven to increase the growth and production of mung bean in acid soils, but has not yet reached the optimal stage, so in the future, a deeper study is needed to analyze other factors that affect the interaction between plants and arbuscular mycorrhizae.

CONCLUSION

The application of dried decanter solid 300 g/polybag significantly increased plant height, the number of branches and seed weight per plot, besides the application of dried decanter solid 450 g/polybag significantly increased root length. Meanwhile, without the application of dried decanter solid, a faster flowering period, more chlorophyll and higher seed weight per plant were obtained compared to the application. The application of arbuscular mycorrhizal fungi and the interaction of the two treatments did not give optimal results on all parameters of the growth and production of mung beans. It remains to be further investigation is needed by increasing the dose of arbuscular mycorrhizal fungi application to obtain optimal results.

SIGNIFICANCE STATEMENT

The application of dry decanter solids aims to increase the availability of nutrients in the soil needed to optimize the growth and production of mung beans in acid soils, then the available nutrients can be properly absorbed by plant roots through symbiosis with arbuscular mycorrhizae which play an active role in colonizing plant root cortex tissue. The results showed that there was an increase in plant growth and production with the application of dry decanter solids and arbuscular mycorrhizae compared to without application. Based on this, a more in-depth study is needed regarding the mechanism of interaction between plants and arbuscular mycorrhizae to determine the effectiveness of use.

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