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Full Length Research Article

Mining Sludge Utilization as Medium Growth for Revegetation Plants through Seed Germination Test

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ABSTRACT

The limited topsoil stock is one of the post-mining reclamation problems that will directly impact the company's business processes. One solution that can be considered to reduce production costs is the utilization of unused materials around the mine. The settling pond sludge contains nutrients and can be used as a growing medium for plants to replace topsoil. This study examined the potential utilization of settling pond sludge through germination and sprout viability tests. This study used a completely randomized design with four composting treatments, namely 0%, 25%, 50%, and 75%. The number of replications was ten times and applied to several species of revegetation plants, namely *Acacia mangium*, *Senna siamea*, *Falcataria moluccana*, and *Albizia saman,* so there were 160 experimental units in total. The results showed that the settling pond sludge has organic matter reserves and low nitrogen content but is rich in P and element reserves of P and K. The physical texture of settling pond sludge was still suitable as a medium for plant growth. The addition of compost as a mixture of settling pond media had a significant effect on germination and germination viability but had no significant effect on the parameters of the germination rate. The increase in compost composition in the settling pond media mixture positively affected germination and germination survival. Based on this research, it is known that settling pond sludge can be used as a medium for growing revegetation plants. In general, the media with the addition of 50% and 75% compost gave the best germination response and viability.

1. Introduction

The process of post-mining land reclamation is inseparable from various obstacles, and each mine has various problems. In general, several obstacles faced in land reclamation are related to low soil fertility, unstable slopes, erosion, sedimentation, limited ameliorant materials, climatic factors, and the formation of acid mine drainage (Iskandar et al. 2012). The limited topsoil stock is one of the problems faced in post-coal mining land reclamation (Susilo et al. 2010). Topsoil is the topsoil layer composed of horizons A, B, and C; this soil material is usually dredged during land clearing and then collected at a location (Sutono et al. 2019). This land will be reused to cover post-mining land and function as a medium for growing revegetation plants. The lack of topsoil stock is thought to be caused by various factors, such as errors in calculating the availability of topsoil stock and its distribution in the field. The lack of topsoil stock will undoubtedly hamper the reclamation process, which will directly impact the company's business processes. Hence, solutions are needed to overcome these problems.

Solutions to post-mining land problems often cost a fantastic amount, such as improving land through fertilization and liming the land. According to Irdika (2013), composting in post-mining land can reach 30 tons/ha. Adding urea, SP36, and KCL fertilizers of 400 g each per planting hole for liming, usually 300 g of super dolomite is added per planting hole. If accumulated, the cost of improving the land can reach hundreds to billions of rupiah per ha. Likewise, the procurement of topsoil material costs a lot and depends on stock availability. Therefore, mining companies need to make adjustments by looking for alternative solutions that are more economical and sustainable. One solution that can be considered to reduce production costs is using unused materials by observing the mining environment. Observation of the environment around the mine is intended to look for materials that have the potential to be reused to handle post-mining land problems.

Environmental observations have been carried out on the post-mining land of PT. Berau Coal, and the fact that there is a material in the form of sludge overgrown with grass and other plants in the expanse of the disposal area. Based on these facts, it is alleged that this sludge material contains nutrients and can be used as a medium for plant growth. The sludge originates from the settling pond and is routinely dredged and discharged to disposal areas. However, research on the utilization of settling pond sludge waste is still minimal. For example, Sari (2017) reported that settling pond sludge could be used as a mixture of brick aggregates. Likewise, Marlina (2019) also reported that this sludge could be used as a planting medium. However, based on these studies, the nutrient content of the settling pond sludge is still not explained in detail, and neither is how the test method was performed.

This research is the initial stage of evaluating the potential utilization of settling pond sludge as a planting medium to replace topsoil. The evaluation was conducted by analyzing the physical and chemical properties of settling pond sludge and testing the germination and viability of several species of revegetation plants in settling pond sludge media and compost with various compositions. The plants tested in this study were revegetation plant species, namely acacia (*Acacia mangium*), johar (*Senna siamea*), sengon (*Falcataria moluccana*), and trembesi (*Albizia saman*). The purpose of this study was to identify the potential utilization of settling pond sludge as a planting medium, identify the germination capacity, germination rate, and viability of sprouts planted in settling pond sludge media, and identify the effect of giving compost as a mixture of settling pond sludge media on germination capacity, germination rate, and germination viability.

2. Materials and Methods

2.1. *Study Area*

The research was carried out from April–May 2022. Observations and data collection were carried out for four weeks at the Lati Site Nursery, PT. Berau Coal, East Kalimantan.

2.2. *Materials*

The materials used are the seeds of acacia (*Acacia mangium*), johar (*Senna siamea*), sengon (*Falcataria moluccana*), trembesi (*Albizia saman*), water, settling pond sludge, and compost.

2.3. Research Procedures

2.3.1. Sampling of settling pond sludge in the nursery

A physical and chemical sampling of settling pond sludge was carried out at Water Monitoring Point (WMP) 7, Lati Site. A sampling of the chemical sludge was carried out by taking several points at random and spreading one kg in the location; then, all the samples that had been obtained were composited by stirring using a hoe. After being composited, 1 kg of sample was taken and put into a plastic sample. The sludge was sampled using two soil sample rings and wooden blocks. The location was chosen randomly. The first sample ring was pressed vertically using a wooden block into the sludge bed. The second sample ring was then placed on top of the first sample ring to push the first sample ring further into the sludge surface. After that, the surface of the sludge around the ring was excavated using a shovel slowly so that the sludge sample contained in the ring was not destroyed. The surface of the sludge was excavated until the entire body of the sample ring was visible. Next, the bottom and top of the first sample ring were cut horizontally using a machete, then the two halves of the ring were closed with a sample ring cover. The physical and chemical samples of the sludge were then sent and tested at the Indonesian Center for Biodiversity and Biotechnology (ICBB) Laboratory, Bogor.

2.3.2. Compost sampling

The compost used in this study was taken from the Lati Site Nursery. First, the compost sample was taken with a shovel of as much as 1 kg from several compost sacks. After that, the samples that had been collected were composited by stirring using a hoe. After the compost was composted, a one kg sample was taken to analyze its nutrient content.

2.3.3. Transportation of settling pond sludge to nurseries

The settling pond sludge was obtained from the expanse of sludge resulting from the dredging of the settling pond at Water Monitoring Point (WMP) 7, Lati Site. First, sludge was collected by hoeing and then putting it in a plastic bag. After that, the packed sludge was transported to the nursery using a light vehicle. Furthermore, the sludge that arrived at the nursery was spilled onto the tarpaulin and composited by stirring using a hoe. Finally, sludge compositing was carried out to obtain uniform sludge properties.

2.3.4. Planting media process

The planting medium used was sludge obtained from settling pond WMP 7, mixed with compost from the Lati Site Nursery. The composted sludge was then added with compost at the ratio of volume per volume (compost volume: volume of sludge), namely 0% (without compost/control), 25% (1:3), 50% (1:1), and 75% (3:1). The volume ratio was measured using a 10-liter plastic bucket. The planting media was mixed and then put into a polybag measuring 20 cm × 20 cm, which was given a treatment mark using a marker.

2.3.5. Seed preparation

The seeds were obtained from the Lati Site Nursery. The number of seeds needed was calculated first; then, the seeds were taken from the seed storage box using a measure from a plastic teapot. The measured seeds were then weighed to obtain the appropriate number of seeds. After all the seeds were obtained, proceed with breaking dormancy. Breaking dormancy was done by soaking the seeds in a bowl of hot water for 1 minute and then soaking them in cold water for 24 hours. After 24 hours, the bowl containing broken dormancy seeds was drained and cleaned of impurities still attached to the seeds.

2.3.6. Seed germination test

The seed germination test was carried out by planting ten seeds whose dormancy had been broken in polybags containing a mixture of topsoil and compost in a 1:1 ratio. A germination test was carried out for the four plant species tested by complete randomization and repeated three times so that the total experimental units were 12. Seeds were watered every day in the morning and evening. Observations were made daily by taking data on the number of seeds that normally germinated, which was then recorded in a tally sheet.

2.3.7. Planting and seeds maintenance

Planting was carried out on the seedling table in the Lati Site Nursery. Polybags containing planting media were arranged on the seedling table according to the plant species. Furthermore, direct seeding was carried out; the seeds were immersed as deep as 0.5 cm in a spread. After that, the seeds were covered with a thin layer of planting media. Seeds planted were as many as 20 seeds per polybag. After planting was completed, the polybag was randomized according to the layout prepared, and maintenance was carried out by watering every morning and evening. In addition, weeding was also carried out.

2.3.8. Observation and data collection

Observations and data collection of seed germination was carried out every day for four weeks in the Lati Site Nursery. Seed germination data observed were the number of seeds that normally germinated per treatment on each species of plant planted. At the end of the observation, data analysis was carried out to obtain data on germination, germination rate, and the percentage of germination life.

2.4. Research Design

This study used a completely randomized design (CRD) with treatment in the form of giving compost, the dose of which was obtained from the percentage of compost with settling pond sludge as the media. The compost treatment was given four levels: control (without compost), 25%, 50%, and 75%. The treatment was repeated ten times, and the design was applied to the four species of plants tested. The total number of experimental units in this study was 160. The following are details of the treatment used: (1) P0 = 100% settling pond sludge, (2) P25 = 25% compost and 75% settling pond sludge, (3) P50 = 50% settling pond sludge and 50% compost, and (4) P75 = 75% compost and 25% settling pond sludge.

2.5. Data Analysis

Data analysis was carried out by calculating the parameters of germination, germination rate, and percentage of germination life using the following equations:

$$Germination\ percentage\ (\%) = \frac{Number\ of\ normally\text{-}germinated\ seeds}{Total\ number\ of\ seeds\ germinated} \times 100\% \quad (1)$$

$$Germination\ rate\ (days) = \frac{N_1T_1+N_2T_2+\cdots+N_xT_x}{Total\ number\ of\ germinated\ seeds} \quad (2)$$

$$Life\ percentage\ (\%) = \frac{Number\ of\ polybags\ containing\ life\ germination}{Total\ number\ of\ planting\ polybags} \times 100\% \quad (3)$$

where N is the normal number of germinated seeds and T is the time required for seeds to germinate (days).

The analysis of variance was carried out on the data obtained using SPSS 25 software. The test decision was based on the p-value obtained; if the p-value > 0.05, then the treatment had no significant effect on the parameters tested and vice versa. Parameters affected by the treatment will then be further tested using Duncan's multiple range test (DMRT) to identify the effect of each given treatment in more detail. In addition, this study also analyzed the physical and chemical properties of settling pond sludge, as well as the nutrient analysis of compost.

3. Results and Discussion

3.1. Results

3.1.1. Physical and chemical characteristics of settling pond sludge

Chemical properties analysis was carried out to identify nutrient content and other chemical characteristics such as pH and CEC values in settling pond sludge. The results of the analysis of the chemical properties of settling pond sludge are shown in **Table 1**. The results showed that the pH of the sludge is very alkaline. The value of C-Organic obtained was 1.86%, and the value of N-total was 0.06%, both of which are classified as very low. The C/N ratio of settling pond sludge tested in this study was still classified as good at 31. The available P_2O_5 obtained was 23.1 mg/kg, which was very high, while the potential P_2O_5 and K_2O values were classified as high. The CEC value was included in the low category (Lembaga Penelitian Tanah 1979).

Table 1. The analysis results of the chemical properties of settling pond sludge

Parameters							
pH (H_2O)	C-Organic (%)	N-Total (%)	C/N ratio	P_2O_5 available (mg/kg)	P_2O_5 potential (mg/100g)	K_2O potential (mg/100g)	CEC (cmol(+)/kg)
11.5	1.86	0.06	31	23.1	56	57	16.23

Several parameters were tested in the analysis of the physical properties of settling pond sludge, namely the texture of 3 fractions, bulk density, particle density, porosity (total pore space), and soil permeability (**Table 2**). The texture of the three fractions was dominated by sand, dust, and clay (**Table 2**). The bulk density value was 1.03 g/cc, and the particle density was 2.34 g/cc. The porosity of settling pond sludge was 55.98%, then the permeability rate obtained was 1.46 cm/hour, which is relatively slow.

Table 2. The analysis results of the physical properties of settling pond sludge

3 fraction texture (%)			Bulk density (g/cc)	Particle density (g/cc)	Total pore space (%)	Permeability (cm/hour)
Sand	Dust	Clay				
79	16	5	1.03	2.34	55.98	1.46

3.1.2. Compost chemical characteristics

Compost is one type of organic fertilizer that supports plant growth by providing essential macro and microelements. Analysis of the chemical properties of compost aims to identify the nutrient content and maturity level of the compost as parameters that can describe the quality of the compost used. The analysis of compost's chemical properties (**Table 3**) shows that the value of C-Organic compost is classified as high with a very low N-Total. The value of the C/N ratio obtained is included in the high category, namely 52. The available P_2O_5 obtained was 1.10%, then the P_2O_5-total and total K_2O obtained were 0.31% and 0.46%, respectively. The values of N-total, P_2O_5-total, and K_2O-total obtained have met SNI 19-7030-2004 with criteria for N-total > 0.40%, P_2O_5-total > 0.10%, and K_2O-total > 0.20%. The pH of the compost obtained was 7.2, which is classified as neutral (Lembaga Penelitian Tanah 1979).

Table 3. The analysis results of the chemical properties of compost

C-Organic (%)	C/N Ratio	N-Total (%)	P_2O_5 Available (%)	P_2O_5 Total (%)	K_2O Total (%)	pH
51.35	52	0.99	1.10	0.31	0.46	7.2

3.1.3. Germination test and seed germination rate

A germination test was carried out in the nursery to control environmental influences. The seed germination test on control media aims to determine the ability of seeds to germinate, usually under optimal environmental conditions, so that the initial potential for seed germination can be known. The results of the test of seed germination percentage and seed germination rate after four weeks of planting the seeds are shown in **Table 4**.

Table 4. Seed germination percentage and germination rate after four weeks of seed planting

Species	Germination percentage (%)	Germination rate (days)
Acacia (*Acacia mangium*)	90.0	4
Johar (*Senna siamea*)	50.0	5
Sengon (*Falcataria moluccana*)	86.7	4
Trembesi (*Albizia saman*)	90.0	10

The results of the seed germination test four weeks after planting showed different germination rates and germination rates for the four species tested (**Table 4**). The germination percentage of acacia and trembesi seeds was 90%, with a germination rate of 4 and 10 days, respectively. Then on sengon seeds, the percentage value for germination was 86.7% with a seed germination rate of 4 days, while johar seed obtained a percent germination value of only 50% with a germination rate of 5 days.

3.1.4. The variance results of the effect of composting on seed germination and sprouts viability

Seed germination parameters obtained in this study were germination and germination rate, while the percentage value of germination life measured the survival parameters. The variance test was carried out to determine the significance of the effect of compost treatment on the value of seed germination parameters. Variance results of the effect of treatment on the germination parameters of the four plant species tested in this study are shown in **Table 5**.

Table 5. The variance results of the effect of composting on seed germination and sprouts viability

Species	Parameters	Treatment
Acacia (*Acacia mangium*)	Germination percentage (%)	*
	Germination rate (days)	ns
	Life percentage (%)	*
Johar (*Senna siamea*)	Germination percentage (%)	*
	Germination rate (days)	ns
	Life percentage (%)	*
Sengon (*Falcataria moluccana*)	Germination percentage (%)	*
	Germination rate (days)	ns
	Life percentage (%)	*
Trembesi (*Albizia saman*)	Germination percentage (%)	*
	Germination rate (days)	ns
	Life percentage (%)	*

Note: * = treatment has a significant effect on the parameters at the 95% confidence interval, ns = the treatment has no significant effect on the parameters at the 95% confidence interval.

The results showed that the compost treatment significantly affected the germination parameters and survival percentage for the four species tested (**Table 5**). In addition, the composting treatment did not significantly affect the seed germination rate.

3.1.5. Post hoc analysis (Duncan's multiple range test)

3.1.5.1. Seed germination percentage

The variance results (**Table 5**) indicate that composting significantly affected the germination parameters of seeds, so post hoc tests need to be carried out to determine the effect of each level of compost treatment given. The results of Duncan's multiple range test (DMRT) are shown in **Table 6**. In general, the results of post hoc tests showed that the 50% and 75% compost treatments gave an average response of germination, which was not significantly different. However, the 50% and 75% compost treatment responses differed significantly from the control and 25% compost treatment responses.

3.1.5.2. Seed germination life percentage

Composting had a significant effect on the average survival percentage of sprouts, so further tests were carried out so that the effect of each treatment could be known. The results of the DMRT can be seen in (**Table 7**). The treatment responses resulting from the DMRT were divided into treatment groups that were significantly different from each other and not significantly different. The response of the average survival percentage from the treatment of 50% compost and 75% compost was not significantly different from each other. However, it differed significantly from the control and 25% compost treatments.

Table 6. Post hoc test using Duncan's multiple range test on the average germination seeds

Species	Treatments	Germination Percentage (%)
Acacia (*Acacia mangium*)	P50	38.9^{b}
	P75	21.2^{ab}
	P0	10.6^{a}
	P25	5.4^{a}
Johar (*Senna siamea*)	P50	7.7^{b}
	P75	6.3^{b}
	P25	1.2^{a}
	P0	1.0^{a}
Sengon (*Falcataria moluccana*)	P50	18.8^{b}
	P75	13.3^{ab}
	P25	2.4^{a}
	P0	1.5^{a}
Trembesi (*Albizia saman*)	P75	26.5^{b}
	P25	16.2^{ab}
	P0	7.4^{a}
	P50	5.6^{a}

Note: the mean value of germination followed by the same letter showed results that were not significantly different at the 5% confidence level.

Table 7. Post hoc test using Duncan's multiple range test on the survival percentage of plant sprouts

Species	Treatments	Percentage of Sprouts Life (%)
Acacia (*Acacia mangium*)	P50	100^{b}
	P75	80^{b}
	P25	40^{a}
	P0	20^{a}
Johar (*Senna siamea*)	P50	70^{b}
	P75	60^{b}
	P25	10^{a}
	P0	10^{a}
Sengon (*Falcataria moluccana*)	P50	100^{c}
	P75	60^{b}
	P25	40^{b}
	P0	0^{a}
Trembesi (*Albizia saman*)	P75	100^{b}
	P25	100^{b}
	P0	90^{ab}
	P50	70^{a}

Note: the mean value of germination followed by the same letter showed results that were not significantly different at the 5% confidence level.

3.2. Discussion

3.2.1. Chemical and physical characteristics of settling pond sludge

The chemical and physical analysis aims to identify the characteristics of settling pond sludge. **Table 1** shows that the C-Organic content of the settling pond sludge is shallow, indicating that the settling pond sludge has low organic matter reserves. The nitrogen content in the settling pond sludge is also shallow, which is indicated by the total N value. The value of the C/N ratio obtained is 31, which is still quite good. Brust (2019) suggested carbon and nitrogen ratios between 20 to 30 as a good balance point between the mineralization process and nitrogen immobilization.

The P element reserves in the settling pond sludge are high, indicated by the high P_2O_5-total value in the sludge nutrient analysis results (**Table 1**). P is a macronutrient needed in significant quantities by plants and is very important to maintain productivity and plant growth (Malhotra et al. 2018). According to Nadeem et al. (2011), element P plays a role in germination, seedling growth and development, and plant reproduction. However, it should be noted that plants cannot utilize all P elements in the sludge media directly; only P elements in available form can be absorbed directly. According to Nursyamsi and Setyorini (2009), P nutrients have immobilized properties because P is primarily absorbed in a form unavailable to plants. Based on the results of nutrient analysis, it is known that the available P content in the settling pond sludge is in the high category, which can be seen from the high available P_2O_5 value. The availability of P in the soil depends on soil pH, organic matter content, number and type of soil minerals, the influence of cations and anions, P saturation level, time, temperature, and inundation (Havlin et al. 1999).

Nutrient reserves of K are also stored in the settling pond sludge, which can be illustrated by the high potential K_2O value (**Table 1**). K is one of the most abundant inorganic cations and is essential in optimizing plant growth (White and Karley 2010). According to Hepler et al. (2001), element K is essential in supporting the growth and development of plant cells, besides that element K also functions as an activator of various enzymes in the process of protein synthesis, sugar transport, C and N metabolism, and photosynthesis (Oosterhuis et al. 2014). Elemental K can be absorbed by plants in the form of soluble K or soluble K (K^+). Several factors affect the availability of K elements, namely the amount and type of clay minerals, soil pH, CEC, temperature, humidity, and aeration. In addition, the level of K uptake also depends on the plant species, and tolerant plants require fewer K elements than sensitive plants (Nursyamsi et al. 2007).

Based on the results of soil chemical analysis (**Table 1**), it is known that the settling pond sludge tested in this study has a low CEC value, so the ability of this sludge to absorb nutrients is classified as poor. The low CEC is thought to be due to the low organic matter reserves in the settling pond sludge, so the decomposition process takes place slowly. Therefore, adding organic matter can increase the low CEC of settling pond sludge. According to Siregar et al. (2017), adding organic matter can increase soil CEC due to the decomposition process of organic matter, which produces humic compounds which will increase soil colloids. The increase in soil CEC occurred due to the addition of negatively charged soil colloids derived from the carboxyl (COOH) and hydroxyl (OH) groups contained in organic compounds.

The results of the physical analysis of the soil (**Table 2**) show some physical characteristics of the settling pond sludge. The settling pond sludge is dominated by the sand fraction, which is 79%, followed by 16% dust fraction and 5% clay fraction. The settling pond sludge is classified as loamy sand texture based on the soil texture triangle. The dominance of the sand fraction in the settling pond sludge shows that this sludge can store water and low nutrients. According to Hidayanto et al. (2004), the soil/media dominated by the sand fraction has a low CEC due to the small amount of negative charge in this fraction; therefore, the ability of the settling pond sludge to adsorb and exchange cations is relatively low. The bulk density value of settling pond sludge is 1.03 g/cc, which is ideal for supporting plant growth. According to USDA (1999), soil/media with loamy sand texture with a bulk density value of < 1.6 g/cc is ideal for plant growth, but if the bulk density value has reached > 1.8 g/cc, then the growth of plant roots will decrease started to get distracted. The settling pond sludge has a porosity of 55.98%, which is still quite good. High porosity will provide space to store air, water, and space for plant roots. Otherwise, low porosity will reduce aeration and water availability and inhibit rooting, which will ultimately have implications for decreased plant productivity. The settling pond sludge permeability rate is 1.46 cm/hour, which is relatively slow (Lembaga Penelitian Tanah 1979). According to Hillel (1971), soil permeability is influenced by texture, structure, aggregate stability, porosity, pore size distribution, pore size continuity, and organic matter content.

3.2.2. Compost chemical characteristics

Chemical analysis of compost aims to identify compost's quality and nutrient content. **Table 3** shows that the C-Organic value of the compost is high with a very low N-Total, so the value of the C/N ratio obtained is included in the high category, namely 52, which has exceeded the maximum limit of the C/N ratio SNI for compost is 20. According to Gani et al. (2021), the C/N ratio is one indicator of the level of maturity and quality of compost; if the value of the C/N ratio is high so the decomposition time of organic matter will be slower. In addition, the chemical analysis of the compost showed that the P_2O_5-available value was 1.10%, then the total P_2O_5 and K_2O-total were 0.31% and 0.46%, respectively. The values of N-total, P_2O_5-total, and K_2O-total obtained have met SNI 19-7030-2004 with criteria for N-total > 0.40%, P_2O_5-total > 0.10%, and K_2O-total > 0.20%. The pH of the compost obtained was 7.2, which was classified as neutral and had met SNI in the pH range of 6.80–7.49 (Lembaga Penelitian Tanah 1979).

3.2.3. Seed germination percentage and germination rate in control media

Seed germination is an important parameter that can describe the ability of seeds to germinate, usually under favorable environmental conditions. Seeds that germinate typically will produce healthy plants with good growth performance. The seeds that usually germinate have characteristics such as good hypocotyl and epicotyl development, normal plumules, and good root development (Taghfir et al. 2018). Tests for seed germination were carried out on control media, using a mixture of topsoil and compost with a ratio of 1:1.

As shown in **Table 4**, it is known that the highest percentage of seed germination is produced by acacia and trembesi seeds, which is 90%, followed by sengon seeds at 86.7%, and johar at 50%. A previous study shows that the results of the germination test of acacia seeds on sand media resulted in lower germination power of 76.5% (Kusuma et al. 2019). Nugroho (2013) reported that the germination test on media topsoil obtained the percentage of germination of trembesi seeds which was also lower at 77%, while in sengon, the percentage of germination was the same, namely 86.7%. Johar seed has the lowest germination percentage compared to other species, which is only 50%. This result indicates that the johar seeds tested in this study had lower seed viability than those of other species. The low viability of johar seeds tested in this study was thought to be due to a decrease in seed quality caused by internal and external factors. According to Paramita et al. (2018), seed viability is influenced by various factors, both internal factors such as genetic characteristics, initial viability, and moisture content, as well as external factors such as type of packaging, temperature and humidity of seed storage space, microorganisms, and human negligence factors.

The seed germination rate was measured to determine the time required for seeds to produce radicles or plumules. The value of the seed germination rate for each plant species tested is shown in **Table 4**. Acacia and sengon seeds had the same germination rate for 4 days, then for johar seeds, the germination rate for 5 days was obtained. The slowest germination rate was found in trembesi seeds (10 days). The germination rate in this study was faster than in previous studies, such as in the study of Kusuma et al. (2019), the results of the germination rate of acacia seeds for 9 days on sand media, and in Nugroho (2013), the results of the germination rate of trembesi for 14 days and sengon for 6 days on topsoil media.

3.2.4. Seed germination percentage and germination rate in settling pond sludge media

The adaptability of seeds to settling pond sludge media was measured by observing the parameters of germination, germination rate, and percentage of germination life. The variance table shows that applying compost as a mixture of settling pond sludge significantly affects the germination parameters of acacia, johar, sengon, and trembesi seeds at a 95% confidence interval (**Table 5**). The results of DMRT (**Table 6**) show that the average response of germination produced by each plant species is different. These responses can be divided into groups of responses that are significantly different from each other or not significantly different.

The average response to germination of 50% and 75% compost treatment was not significantly different from each other in acacia, sengon, and johar. However, it resulted in a higher average response of seed germination when compared to the control treatment (without compost) and 25% compost. However, giving 50% compost treatment to johar resulted in a lower average response of germination when compared to the responses of other treatments. Acacia produced the highest average germination response (38.9%), followed by trembesi (26.5%), sengon (18.8%), and johar (7.7%).

The response of the average germination rate decreased along with the composition of the compost in the settling pond media mixture, which was indicated by a decrease in the average germination value in the treatment with the lower compost composition, namely 25% compost treatment and control. This phenomenon occurred in acacia, johar, and sengon, while in trembesi, the treatment with 25% compost gave the highest average germination response. The lowest average germination response was found in acacia, which was 1%. In comparison, the lowest average germination in other species was 5.4% for johar, 1.5% for sengon, and 5.6% for trembesi. Seed germination, which is still low, can be increased by using seeds with better initial viability and increasing the number of seeds planted per polybag.

The application of compost is thought to have changed the composition and characteristics of the seed-growing media, which has implications for seed germination activity. According to Chu et al. (2022), seed germination is affected by temperature, sowing depth, salinity, and soil pH. The physical properties of settling pond sludge can be improved by adding compost which can reduce the bulk density and density of the sludge media. In addition, soil physical properties such as bulk density, total porosity, water content, and soil permeability can be improved by adding compost (Barus 2016). Improving the physical properties of the soil will maintain the availability of water in the media, so it will be easier for the seeds to get the water to start the germination process.

The table of variance shows that the application of compost did not significantly affect the germination rate of each plant species tested (**Table 5**). This result is presumably because the seeds were planted at the same depth in each treatment medium and not far from the surface, which is 0.5 cm deep. This result makes the composition of each medium not have a natural effect, so the seeds have the same opportunity to grow. However, according to Ahmed et al. (2019), the depth of sowing can affect seed germination; the more profound the seed is planted, the lower the seed germination will be because plumules take longer to reach the surface (emerging).

3.2.5. The percentage of sprouts life in settling pond sludge media

The survival parameters of sprouts manifest the resistance of sprouts in adapting to their environment and the treatment given in an experiment. Viability is measured in terms of survival percentage, which is the percentage of the ratio of the number of sprouts that are still alive to the total number of seeds planted. The variance (**Table 5**) shows that the compost treatment significantly affects the response of the average survival percentage of the four plant species tested. The results of DMRT (**Table 7**) show that the average response of the highest percentage of survival for acacia and sengon resulted from the provision of 50% compost treatment, i.e., an average response of 100% survival was obtained. Johar resulted in the highest average survival percentage response from the 50% compost treatment, which was 70%. The average response of the highest survival percentage in trembesi was found in the treatment of 75% and 25% compost, which was 100%. The average response of the percentage of survival resulting from the administration of 75% and 50% compost was not significantly different from each other in acacia and johar, whereas, in sengon and trembesi, the average response of the survival percentage from the administration of these two treatments was significantly different from each other. Lower survival rates were produced by control treatment and 25% compost on acacia, johar, and sengon, namely 20%, 10%, and 0%, respectively. However, giving 25% compost treatment to trembesi resulted in a high life expectancy of 100%. Based on this phenomenon, it can be seen that, in general, each species tested can adapt and grow in the settling pond sludge media. However, a decrease in compost composition in the settling pond sludge mixture will cause a decrease in the percentage of life and even death of sprouts in certain plants.

Increasing the compost composition in the settling pond sludge has a positive effect on the viability of the sprouts. It has been reported in several studies that plant viability can be increased through the application of organic fertilizers. Rizkyandana (2021) reported that applying compost to soil media contaminated with acid mine drainage can increase the viability of eucalyptus plants by up to 50%. Pratama (2021) found that the survival rate of gempol plants could be increased up to 20% with the addition of goat manure. On media contaminated with acid mine drainage. Composting can also increase plant growth, which can also be an indicator of plant survival and adaptability. Wasis et al. (2011) reported that applying compost to gold mine tailings media can increase the growth of mahogany sprouts by up to 40.7% and diameter growth by up to 17.3%. Applying organic fertilizers such as compost can improve the growing media's physical, chemical, and biological characteristics, producing more optimal plant growth media. Compost is known to improve soil structure and contains a complete variety of macro- and micro-nutrients, the amount of which varies depending on the material of origin (Simanungkalit et al. 2006). In addition, compost can also significantly improve the microbiome of the soil (Strachel et al. 2017). The presence of microorganisms in the soil will improve soil structure, increase nutrient availability, produce phytohormones, stimulate plant growth, and act as phytopathogen biocontrol, bioaccumulation of inorganic compounds, to bioremediation of polluted soil (Singh et al. 2019).

4. Conclusions

Settling pond sludge has the potential to be used as a medium for growing revegetation plants, especially for the growth media of the species tested in this study, namely acacia (*Acacia mangium*), johar (*Senna siamea*), sengon (*Falcataria moluccana*), and trembesi (*Albizia saman*). The settling pond sludge has organic matter reserves and low nitrogen content but is rich in nutrients and P nutrient reserves, as well as K element reserves. The physical texture of settling pond sludge is dominated by sand, so the ability to absorb nutrients and water is low in bulk density. Nevertheless, the porosity of this sludge is still feasible to be used as a medium for plant growth. The addition of compost as a mixture of settling pond media had a significant effect on germination and germination viability but had no significant effect on the parameters of the germination rate. However, the increase in compost composition in the settling pond media mixture positively affected germination and germination survival. In general, media with a mixture of 50% and 75% compost gave the best germination response and germination viability. Further research is needed on cultivating revegetation plant species in settling pond sludge media on laboratory and field scales with a more extended research period to test and confirm the level of resistance and growth performance of revegetation plants.

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