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Phytoremediation potential of some grasses on lead heavy metal in tailing planting media of former tin mining

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Abstract. *Khodijah NS, Suwignyo RA, Harun MU, Robiartini L. 2019. Phytoremediation potential of some grasses on lead heavy metal in tailing planting media of former tin mining. Biodiversitas 20: 1973-1982.* Agricultural production on tin tailings land must consider the safety of products from Pb metal contaminants. The presence of Pb metal can be overcome by using plants as phytoremediation. This study aimed to obtain information on the ability of phytoremediation of Pb by various types of grass and its interaction with the types of ameliorants in tin tailings media. Three species of grass were used, namely *Pennisetum purpureum, Saccharum spontaneum*, and *Hymenachne acutigluma*, and two types of ameliorant, namely lime and compost. The study was designed using a factorial treatment design laid out in a completely randomized design with two treatment factors, namely the type of grass and the type of ameliorant. Observations were done on growth, shoot Pb content and root Pb content. The ability of phytoremediation was assessed by using the approach of Bioconcentration factor (BCF) and Translocation Factor (TF) values. The highest phytoremediation ability was found in treatment of *H. acutigluma* grass treated with lime ameliorant, followed by *S. spontaneum* treated with lime ameliorous and *S. spontaneum* treated with compost ameliorant. Based on BCF values, *P. purpureum* and *H. acutigluma* were categorized as accumulators, and *S. spontaneum* was classified as an excluder. Based on TF values, the three types of grass used were classified as phytostabilisation. The high ability of phytoremediation in *H. acutigluma* was caused by its high BCF values, while the high ability of phytoremediation on *S. spontaneum* was caused by its low translocation factor value and high Pb absorption efficiency.

Keywords: *Hymenachne acutigluma,* lead*, Pennisetum purpureum,* phytoremediation*, Saccharum spontaneum*

INTRODUCTION

Lead (Pb) is considered to be the most toxic environmental pollutant due to its toxicity and nonbiodegradability properties (Lou et al. 2013; Pinho and Ladeiro 2012). Pb in tin tailings land of the multiplier location reached 60.1 ppm for land that has been abandoned for more than 40 years (Ferry et al. 2013), and in refined tin tailings land, it can reach 50.53 ppm (Sari 2015). The absorption of metals from the soil depends on different factors such as soil pH, plant growth stage, species, fertilizer and soil type (Kooner et al. 2014). Heavy metal toxicity and mobility depend not only on the total amount but also on the chemical fractionation on the ground (Yang et al. 2014). Therefore, it is necessary to choose a type of strategy for revegetation of post-mining land (Antwi et al. 2014) of which the vegetation can act as an absorber of Pb (Nascimento et al. 2014).

Phytoremediation method is the use of plants to extract, neutralize, accumulate and/or reduce contaminants from soil, water or air (Gerjardt et al. 2016) and is an effective and economical strategy for transporting heavy metals from the soil (Nascimento et al. 2014; Sarwar et al. 2017). Phytotoxicity is useful for reducing the risk associated with heavy metal contaminants through the use of hyperaccumulators (Pinho and Ladeiro 2012). The species used for revegetation and phytoremediation must have rapid growth potency and free of diseases and pests. They must be able to compete with less desirable species, capable to adapt to local soil and climatic conditions, and also able to grow in poor soils (Ranjan et al. 2015).

The selection of locally and perennial invasive grasses such as West Indian marsh grass or *rumput kumpai* (*Hymenachne acutigluma* (Steud.) Gilliland.), napier grass or *rumput gajah* (*Pennisetum purpureum* Schumach) and wild sugarcane or *rumput gelagah* (*Saccharum spontaneum* L.) is expected to be the choice of pioneer vegetation to restore the ecological functions of the soil after tin mining. Grasses are chosen because of their resistance to extreme post-mining conditions (Chuan et al. 2016), phytoremediation ability, and their subsequent economic value as feed that might be developed after mining. *H. amplexicaulis* was the favorite food of swamp buffalo (Windusari et al. 2014); in Australia, *H. amplexicaulis* is considered an invasive species (Grice et al. 2011) and is a perennial grass that could produce large amounts of biomass in the dry and rainy seasons (Magnano et al. 2018). *P. purpureum* is a plant species with high biomass production (Arunothai et al. 2014) as a potential bioenergy plant and can be a useful habitat for arthropods (Aparecida et al. 2014; Xavier et al. 2017). *S. spontaneum* is a grass species able to grow in heavy metal dumps (Nidaa et al. 2017) and it has the potential to restore fly ash deposits (Pandey et al. 2015; Mukharjee et al. 2017).

Some soil amendments can be implemented to improve sandy soils, among others by adding organic matter, along with polymer fertilizers and selecting local species which are also adapted as pioneer vegetation (Oktavia et al. 2015). Pioneer plants can survive in the tailing environment with nutrient stress, high temperatures, and limited water, while other plants have not been able to live in such conditions. Efficiency of phytoextraction can be increased by crop cultivation management including soil management to improve metal tolerance, translocation and metal accumulation in plants (Sheoran et al. 2016). Amendments are used to increase biomass, including nitrogen, phosphorus and potassium (NPK) fertilizer, and sludge (Chirakkara et al. 2016: Zhang et al. 2016).

Bioconcentration factor (BCF) is used as an illustration of plant strength in accumulating Pb in tailings. The translocation factor (TF) shows the ability to transfer metals from the roots to the tops of plants. Bioconcentration factor (BCF) value and Translocation Factor (TF) values-based approaches can be used as indicators of the phytoremediation ability (Ghosh and Singh 2005; Sharma et al. 2010).

The aim of this study was to obtain information on the ability of phytoremediation of Pb by grasses due to the interaction of treatment of grass types and ameliorant types in tin tailings, and to study the factors involved based on growth, shoot and root Pb contents, absorption efficiency, Bioconcentration factor (BCF) and Translocation Factor (TF). This research is expected to contribute to obtaining effective, safe and economical ways of using tin tailings for agricultural activities.

MATERIALS AND METHODS

Research site

The present study used tailings media originating from the tin mining area located in Riding Panjang Village, Merawang Sub-district, Bangka District, Indonesia. The mining locations had not been operated in the last 20 years. Tailing sand was placed in pots and maintained in the experimental farm of the Faculty of Agriculture, Fisheries and Biology, University of Bangka Belitung, Indonesia. Planting of the grasses was started from May to October 2017. Analysis of Pb metal in tailing media and plant tissue Pb was done in the Soil Laboratory of University of Bangka Belitung, Indonesia and SEAMEO BIOTROP Bogor, Indonesia from August to December 2017.

Research design

The study was carried out using a factorial treatment design laid out in a completely randomized design. Two treatment factors were used, i.e., the first factor was the type of grass and the second factor was the addition of ameliorants to the tailing media. The type of grass used consisted of three species of grasses from the Poaceae grass family, namely: *Hymenachne acutigluma, Pennisetum purpureum,* and *Saccharum spontaneum*. The treatment factor of ameliorant addition consisted of two levels, i.e., Dolomite lime and compost. In total, there were six treatment combinations, each was six replications.

Research materials

The planting materials used were three types of grass: *P. purpureum, S. spontaneum* and. *H. acutigluma*. Ameliorants used were: agricultural dolomite lime ($CaCO_3$) and organic matter in the form of compost. NPK inorganic fertilizers (15: 15: 15) were used as additional nutrients in all treatment media.

Preparation of planting media

Tailings were placed in special pots with controlled aeration arrangements to maintain washing of nutrients from the growing media. For each type of grass, two types of ameliorants were added to the planting medium, the first type of ameliorant was lime. Lime was added to the tailings medium as much as 40 g of lime pot^{-1} or equivalent to 6.8 tons ha^{-1}, the time of lime administration was two weeks before planting and was continued after one week of after planting with the administration of 6 g of NPK fertilizer per pot, equivalent to 100 kg ha^{-1}. The second type of ameliorant was compost. Compost was added to the media as much as 0.9 kg of compost pot^{-1}, equivalent to 15 t ha^{-1}. Compost was provided two weeks before planting, and then one week after planting. Provision of NPK fertilizer was at a rate of 6 g pot^{-1} or equivalent to 100 kg ha^{-1}

Planting of grasses

Planting materials consisted of three types of grass. Planting materials of *H. acutigluma* were in the form of tillers with the leaves were cut 15 cm long and roots were about 1 cm, each pot was planted with five tillers. *P. purpureum* and *S. spontaneum* planting materials were in the form of 15 cm long cuttings with two buds, one cutting was planted in each pot. Then, the planting materials were planted in the media according to each type of treatment as previously determined.

Plant maintenance

The grasses were maintained for 135 days with scheduled watering. Weeding and pests and diseases control were carried out manually. After 135 days, the grasses were harvested to collect data on the grass shoot and root dry weight; the Pb metal concentration on the grass tissue; and the Pb concentration on the tailing media after the grass planting was completed. Harvested grasses were cleaned from the soil and the dirt attached to them was cleaned by using running water. Drying of biomass was done using an oven at 100°C for 24 hours, and after a constant weight was reached. The shoot and root dry weight were then measured.

Pb metal extraction

Sampling of plants was carried out by taking one complete grass plant with roots and shoot of each type of soil. The first process carried out after sampling was cleaning of the plant to ensure that there was no soil attached to the roots or leaves. Plants that have been separated by roots and leaves were then weighed. After that, each of the roots and leaves was chopped into small sizes, and was then re-weighed for roots, leaves, and soil. After that, the sample was dried using an oven at a temperature of 120°C for 2 hours. After ensuring that the samples were completely dry, then the samples were weighed and the dry weight was recorded. Some of the samples that had been treated were put into a beaker and provided with HCl and HNO_3 in a ratio of 1: 3 as much as 10 mL (HCl and HNO_3 were used to remove calcium and magnesium mineral crust that attaches to metals), then the samples were kept for 2 days. After 2 days, heating is done at 100°C is done using the oven, after the yellow vapor runs out the temperature is increased to 200°C The destruction is terminated when it is out white steam and liquid in the flask left around 0.5 mL (for one hour). Cool and dilute with H_2O and the volume is adjusted to 50 mL, shake until homogeneous, leave overnight or filtered with W-41 filter paper to obtain clear extract Extract is cooled then diluted with ion-free water to 25 mL, then shaken until homogeneous, leave overnight. Clear extracts were used to measure heavy metals Pb, Cd, Co, Cr, Ni, As, Sn, Ag, Se, Mo using Atomic Absorption Spectrophotometry (AAS) or SSA Flame method for ppm concentration level (Soil Research Institut 2009).

Observation of variables

Observation of pH, CEC and Pb concentration of tailings media after planting were used as supporting data. The main observation data were shoot dry weight, root dry weight, shoot Pb content and root Pb content. The main observation data were subjected to ANOVA of factorial Completely Randomized Design to see the effect of treatment interactions between the type of grass and the type of amelioration on the observed variables. The supporting and main observed data were used to calculate the shoot absorption efficiency, root absorption efficiency, bioaccumulation factor (BCF), translocation factor (TF), and phytoremediation ability.

Efficiency of Pb absorption was calculated by the formula (Baker 1981):

$$\text{Absorption Efficiency of Pb (\%)} = \frac{\text{Pb content in Dry weight of plants (mg/plant)}}{\text{Pb content in the soil (mg/kg)}}$$

The ability to accumulate Pb metal in the soil and translocate it to shoots was determined by the value of bioconcentration factor (BCF) and translocation factor (TF), calculated by the following formulas (Sharma et al. 2010; Ng et al. 2016):

$$\text{Bioconcentration Factor (BCF)} = \frac{\text{Pb root content (mg/.kg)}}{\text{Pb content in the soil (mg/.kg)}}$$

$$\text{Translocation Factor (TF)} = \frac{\text{Pb shoot content (mg/.kg)}}{\text{Pb root content (mg/.kg)}}$$

BCF values were used to assess the ability of grass to accumulate Pb metal from the media. The criteria used for BCF values are: if the BCF value is > 1, then the grass is classified as an accumulator, and if the BCF value is <1, then the grass is classified as an excluder. Whereas, the ability of Pb metal translocation from root to shoot was determined by translocation factor value (TF). If the TF value is >1, the mechanism of Pb transfer by grass is classified as phytoextraction and if the TF value is <1, the mechanism of Pb translocation by grass is classified as a phytostabilization mechanism (Ng et al. 2016). The TF and BCF variables were used to assess the ability of grass to remediate Pb, where phytoremediation is the difference between BCF and TF (Baker 1981).

Data analysis

Data on shoot dry weight, root dry weight, shoot Pb content, and root Pb content, were processed using ANOVA with factorial Completely Randomized Design to see the effect of interaction between types of grasses and types of amelioration on the observed variables. The difference between treatment means was determined by an LSD (Least Significance Different) test with a significance level of LSD (α = 5%) and LSD (α = 1%). Data Analysis was performed by using the assistance of EXCEL macros to perform basic statistical analysis on routine agricultural experiments, DSAASTAT Ver.1.021.

RESULTS AND DISCUSSION

pH conditions and cation exchange capacity of tailings media

The media was 100% sand with a texture of almost sandy. pH of KCl (1: 1) of 4.70 was classified as acidic, total N (%) of 0.01, P-Bray I (ppm) of 2.70, K-dd (m /100 g) of 0.06, Ca (me/100 g) of 0.30, Mg (me/100 g) of 0.13, each was in very low criteria. Meanwhile, the initial Pb content was 27.6 ppm. After treatment, the final tailings pH of the study was still in highly acidic to acidic range. Increase of pH can occur with the addition of lime, but the addition of compost can cause a decrease in pH, especially after planting of *P. purpureum* and *S. spontaneum*. Cation exchange capacity (CEC) was very low, addition of lime and compost ameliorants was able to increase the CEC value but it remained in very low category. CEC increase in compost ameliorant was higher than that of limestone ameliorant (Table 1).

The effect of grass types and types of ameliorant treatments and their interactions on observed variables

There was no significant interactions effect of types of grass by types of ameliorant on almost all observation variables, except for shoot dry weight and efficiency of shoot Pb uptake that was highly significantly affected. The effect of single factor treatment of grass species was highly significant on almost all the observed variables, but its effect on shoot Pb content and Phytoremediation was not significant. Meanwhile, the single factor types of ameliorant significantly affected shoot and root dry weight, efficiency of shoot and root Pb uptake but had no effect on both shoot Pb content and root Pb content, BCF, TF, and phytoremediation ability (Table 2).

Table 1. pH and CEC at the end of planting of tailings media

Variable	Types of grass	Types of ameliorant			
		Lime	Criteria*	Compost	Criteria*
pH, KCl (1: 1)	*P. purpureum*	5.2	Acidic	3.70	Highly acidic
	S. spontaneum	5.7	Slightly acidic	3.70	Highly acidic
	H. acutigluma	5.1	Acidic	4.90	Acidic
Cation Exchange Capacity (CEC) (me/100 g)	*P. purpureum*	0.83	Greatly low	2.09	Greatly low
	S. spontaneum	0.83	Greatly low	2.09	Greatly low
	H. acutigluma	0.92	Greatly low	0.84	Greatly low

Note: * Bogor soil research center (2005).

Table 2. The ANOVA results observed variables under the treatments of types of grass and types of ameliorant and their interactions

Variable	Effect	Types of grass	Types of ameliorant	Interactions	C.V. (%)
Shoot dry weight (g)	ProbF	1.550E-08	4.784E-03	2.942E-04	16.22
	Sign.	**	**	**	
Root dry weight (g)	ProbF	2.371E-06	8.632E-03	2.234E-01	21.40
	Sign.	**	*	ns	
Shoot Pb content (mg/100g)	ProbF	0.076540	0.384932	0.123218	11.51
	Sign.	ns	ns	ns	
Root Pb content (mg/100)	ProbF	0.012132	0.108997	0.449626	19.49
	Sign.	*	ns	ns	
Shoot efficiency of Pb Absorption (%)	ProbF	5.329E-05	3.464E-03	1.029E-02	25.07
	Sign.	**	**	*	
Root efficiency of Pb Absorption (%)	ProbF	1.642E-05	1.028E-02	4.833E-01	26.84
	Sign.	**	*	ns	
Bioacumulation concentration factor (BCF)	ProbF	0.043909	0.269687	0.503637	26.30
	Sign.	*	ns	ns	
Tranlocation Factor (TF)	ProbF	7.830E-08	1.130E-01	2.816E-01	21.80
	Sign.	**	ns	ns	
Phytoremediation ability	ProbF	0.082174	0.185472	0.391632	27.22
	Sign.	ns	ns	ns	

Note: ** = highly significant (p <0.01) and * significant ((p <0.05), ns = not significant. CV: coefficient of variation (%)

Table 3. Means of shoot dry weight and efficiency of Pb absorption on shoots in the interaction between treatments of types of grass and types of ameliorant

Grass species	Types of ameliorant	
	Lime	Compost
Shoot dry weight (g plant^{-1})		
P. purpureum	276.0 d	336.4 c
S. spontaneum	454.9 b	759.4 a
H. acutigluma	108.3 f	137.8 e
LSD (p= 0.05) $_{int}$	28.79	
Shoot efficiency of Pb absorption		
P. purpureum	7.4 c	10.0 b
S. spontaneum	11.6 b	27.5 a
H. acutigluma	3.9 d	5.0 d
LSD (p= 0.05) $_{int}$	1.96	

Note: The numbers followed by different letters in each variable indicate a significant difference in LSD (Least Significance Different) with lowercase letters for the significance level of LSD (p =0.05)

Shoot dry weight and shoot efficiency of Pb absorption

H. acutigluma has different shoot and root shapes than *P. purpureum* and *S. spontaneum*, but *P. purpureum* and *S. spontaneum* have similar form of shoot and roots. The ANOVA results showed a significant interaction effect between grass type as and types of ameliorant on shoot dry weight and efficiency of Pb abruption (Table 2). The results of LSD test (p = 0.05). Table 3 showed that the highest dry weight of shoots was found in *S. spontaneum* which was planted in media equipped with compost, followed by the same grass planted in lime-fed media. This shows that *S. spontaneum* produces the highest dry weight of shoots regardless of the type of ameliorant provided in the growing media. This is because naturally, *S. spontaneum* growth is indeed better able to survive on critical land with high Pb exposure conditions (Mukharjee et al. 2017).

The efficiency of Pb absorption in *S. spontaneum* on media with compost ameliorant differed significantly from other treatments. In this condition, *S. spontaneum* has the highest efficiency of Pb absorption (Table 3). This can be caused by an increase in biomass which can also lead to increased efficiency of Pb absorption as stated by Ameen et al. (2018) that increase in efficiency of Pb uptake by plants will increase in line with the increase in biomass production.

Root dry weight, shoot and root Pb content, roots efficiency of Pb absorption and phytoremediation ability

The interaction treatment between grass type and ameliorant type did not significantly affect root dry weight, shoot and root Pb content, roots efficiency of Pb absorption and phytoremediation ability (Table 2), but it is seen that the addition of compost tends to cause increase of root growth (Figure 1.A), decrease of shoot and root Pb content (Figure 1.B), increase of root efficiency of Pb absorption (Figure 1.C) and decrease of phytoremediation ability in *H. acutigluma* and *P. purpureum* and increase of phytoremediation ability in *S. spontaneum* (Figure 1.D).

The shoot Pb content of *S. spontaneum* exceeded that of *P. purpureum* and *H. acutigluma*; on the contrary, the root Pb content of the *H. acutigluma* was higher than that of the *S. spontaneum* and the *P. purpureum*. The high root Pb content of *H. acutigluma* causes the overall Pb network to be able to exceed the *S. spontaneum* and *P. purpureum* (Figure 2.A and 2.C). The root and shoot Pb contents of lime ameliorant treatment was higher than that of composted ameliorant treatment (Figure 2.B and 2.D).

Although shoot and root Pb contents under lime ameliorant treatment were higher than the compost treatment, but the ratio between shoot Pb content and root Pb in compost ameliorant (1.05) was higher than root-shoot Pb ratio in lime ameliorant (0.94). This indicates that lime has a higher ability to increase root Pb than compost, and conversely, compost has a higher ability to increase shoot Pb than lime ameliorant. The difference in Pb content between types of grass and type of plant organ can be caused by differences in root and shoot systems in the three types of grass used. *S. spontaneum* and *P. purpureum* rooting are relatively similar but *H. acutigluma* was found to have finer and denser roots than *P. purpureum* and *S. spontaneum*. According to Datta et al. (2017), metal accumulation can differ between plants, caused by differences in the root system. Fibrous roots can cause large surface absorption areas in the root system.

According to Ukhopadhyay and Aiti (2010), plants with high biomass and fast-growing tend to have better metal absorption and metal translocation. This can be seen in the highest efficiency of Pb absorption occurring (Figure 2.E and 2.F). The efficiency of Pb uptake in compost ameliorant was higher that the lime ameliorant. Addition of compost to sand-dominant soils such as tailings causes reduced washing of nutrients from the medium so that nutrients are more available (Sabeen et al. 2013). Addition of compost to three types of grass caused an increase in root dry weight and shoot dry weight. Furthermore, according to Sheoran et al. (2016) and Zhang et al. (2016), increase of growth can result in an increase in Pb accumulation. But in this study, the opposite situation did happen, where the compost treatment successfully increased the growth but not the Pb content in the shoots and roots. The results showed an increase in growth due to compost (Table 1) causing a decrease in shoot and root Pb contents (Figure 2.D).

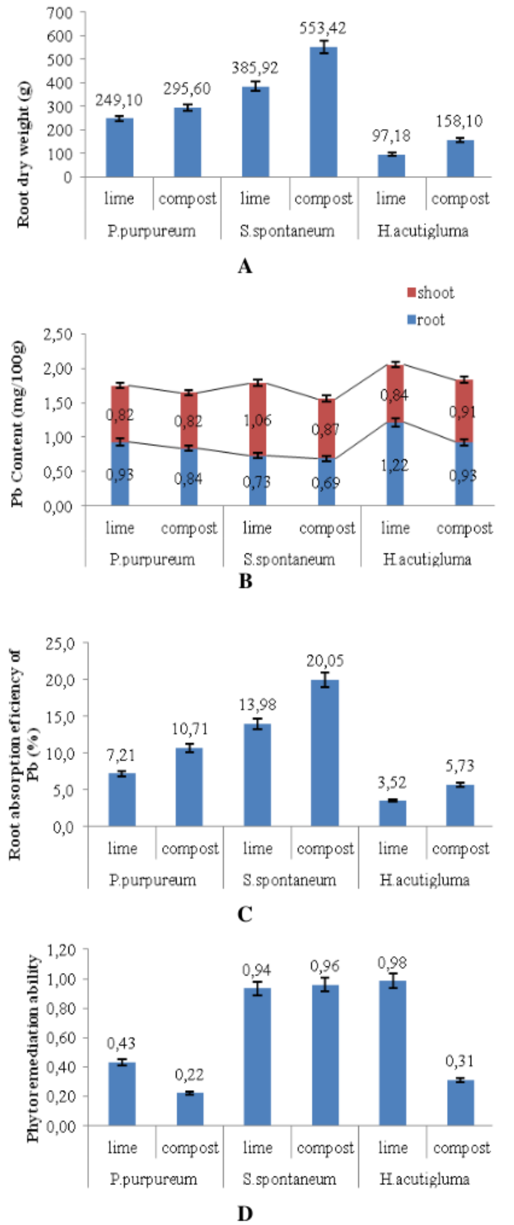

Figure 1. A. Root dry weight, B. Shoot and root Pb content, C. Roots efficiency of Pb absorption, D. Phytoremediation ability on interactive treatment between the type of grass and the type of ameliorant

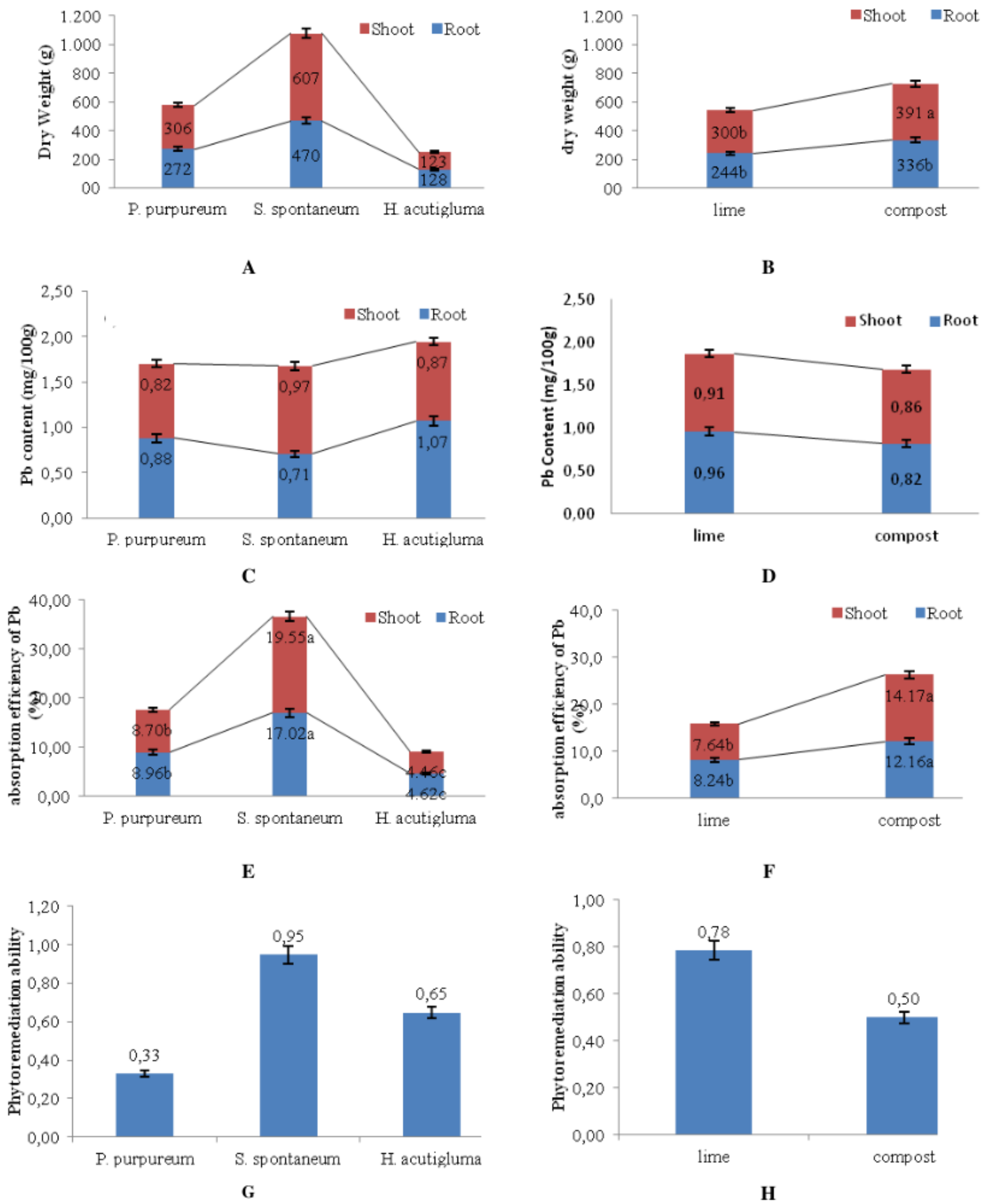

Figure 2. A. Shoot and root dry weight in the single factor treatment of grass type, B. Shoot and root dry weight in the single factor treatment of ameliorant type, C. Content shoot and root Pb in the single factor treatment of grass type, D. Shoot and root Pb content in the single factor treatment of ameliorant type, E. Shoot and root Efficiency of Pb absorption in the single factor treatment of grass type, F. Shoot and root efficiency of Pb absorption in the single factor treatment of ameliorant type, G. Phytoremediation ability. Pb in the single factor treatment of grass type, H. Phytoremediation ability in the treatment of single factor type ameliorant. nOTE: The numbers followed by different letters in each variable indicate a significant difference in LSD (Least Significance Different) with lowercase letters for the significance level of LSD (p = 0.05)

In the interaction treatment between grass type and ameliorant type, although it did not significantly affect the shoot Pb content and root Pb content, the interaction between grass type and ameliorant type significantly affected the efficiency of Pb uptake in shoots (Table 2). In *P. purpureum* and *H. acutigluma*, a decrease in shoot Pb content and root Pb content was followed by a decrease in phytoremediation values, despite an increase in absorption efficiency. In *S. spontaneum,* there is a slightly different tendency; there was a decrease in shoot Pb content and Pb root in *S. spontaeum* followed by increased phytoremediation ability (Figure 2.G and 2.H). This is thought to be due to the greater efficiency of Pb uptake in *S. spontaneum* as compared to the increase in absorption efficiency in *P. purpureum* and *H. acutigluma* (Figure 2.E).

Bioconcentration factor (BCF) and Translocation Factor (TF).

Table 4 shows that even though different types of ameliorants were provided, it did not cause changes in the criteria for grass species based on BCF and TF values.

BCF is a reflection of the ability of plants to hold root Pb. Among these three grass species, *P. purpureum* and *H. acutigluma* have better ability to hold Pb rooted than *S. spontaneum* (Table 4; Figure 3.A). Accumulator plants are able to survive even though the concentration of contaminants in their body tissues is very high. These plants are able to remodel contaminants in their body tissues (Tangahu et al. 2011). Whereas, metal excluder is a type of plant that performs basic strategy by preventing metals from entering the shoots by limiting the metal to remain rooted; this can be done by changing the membrane permeability or changing the cell wall capacity to binding or releasing metal chelating compounds so that the metal concentration around its roots remains low and constant (Cunningham et al. 1995).

Translocate factor (TF) values indicated that all three types of grass have phytostabilization properties (Table 4; Figure 3.B and 3.D). Phytostabilization is a process of immobilizing contaminants in the root area by certain compounds released by plants. Plants can stabilize Pb in the soil, making them harmless (Lamria and Patricus 2015). BCF increases with lime addition compared to composting (Figure 3.A and 3.C.). This shows an improvement in pH causing more roots to hold Pb compared to compost ameliorant. Tailings media that use ameliorants to increase pH (lime) can increase tolerance to heavy metals; this occurs in *Triticale*, *Helianthus annuus* and *Brassica juncea* grown on soil contaminated with heavy metals (Chirakkara et al. 2016).

The ability of phytoremediation is reflected by the ability to hold metal at the root (BCF) reduced by the ability of metal translocation to shoot (TF). Based on this, the ability of BCF is important. This is in line with Xu et al. (2017) who stated that roots have a more important role than shoots in remediating Pb-contaminated soils. TF values also influence the ability of phytoremediation. A high TF value will reduce the value of phytoremediation. Besides being determined by BCF and TF values, the role of absorption efficiency and absorption capacity is also worth taking into account (Chirakkara et al. 2016).

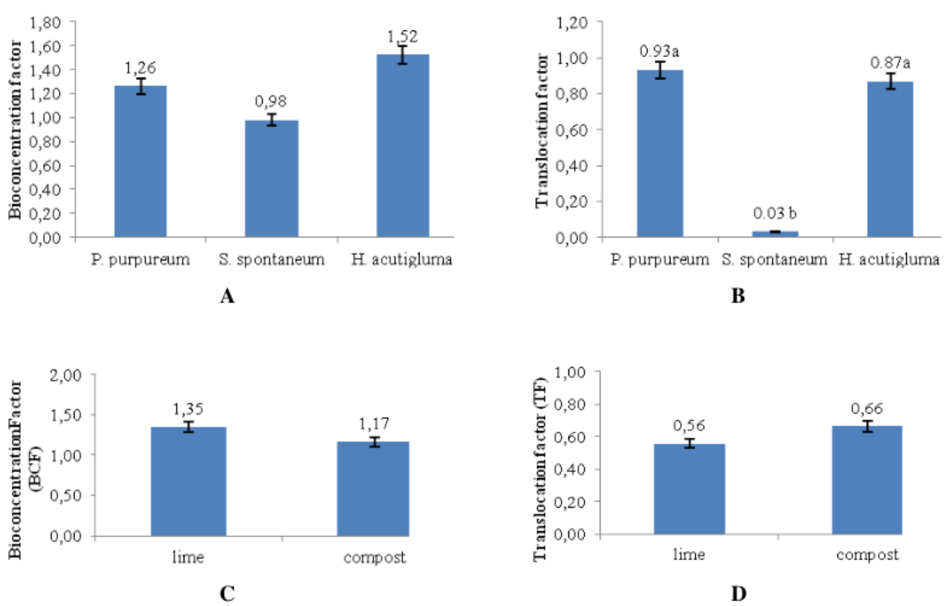

Figure 3. A. Bioconcentration factor (BCF) on various types of grass, B. Translocation factor (TF) on various types of grass, C. Bioconcentration factor (BCF) in various types of ameliorant, D. Translocation factor (TF in various types of ameliorant. Note: The numbers followed by different letters in each variable indicate a significant difference in LSD (Least Significance Different) with lowercase letters for the significance level of LSD (p = 0.05)

Table 4. Grasses criteria based on the value of Bioconcentration Factor (BCF) and Translocation Factor (TF)

Variable	Types of grass	Types of ameliorant			
		Lime	Criteria	Compost	Criteria
Bioconcentration factor (BCF)	*P. purpureum*	1.32	Accumulator	1.20	Accumulator
	S. spontaneum	0.97	Exluder	0.98	Exluder
	H. acutigluma	1.74	Accumulator	1.31	Accumulator
Translocation factor (TF)	*P. purpureum*	0.89	Phytostabilisation	0.98	Phytostabilisation
	S. spontaneum	0.04	Phytostabilisation	0.02	phytostabilisation
	H. acutigluma	0.75	Phytostabilisation	0.99	Phytostabilisation

The lowest translocation value of 0.03 was found in *S. Spontaneum*. This indicates that *S. spontaneum* translocation ability was the lowest. Even though the *S. spontaneum* BCF value was lower but the TF *S. spontaneum* value is also low, the resulting phytoremediation value remains high (Figure 1.E). Increased growth due to compost promotes increased Pb translocation capacity in tissues (Figure 2.D). Increased nutrient in grass can increase metal Pb translocation factors from soil to root and from root to shoot (Arunothai et al. 2014; Ameen et al. 2018; Chuan et al.(2016).

This is thought to be related to increased nutrient uptake efficiency in *S. spontaneum*, *P. purpureum* and *H. acutigluma* (Figures 2.B and 2.D). In addition, this also occurs as a result of roots developing better, so that growth also gets better overall (Figure 2.A and 2.G). Then there will be an increase in the efficiency of Pb absorption. This was found in *S. spontaneum*, which had the highest absorption efficiency compared to *H. acutigluma* and *P. purpureum* (Figure 2.C and 2.E).

This was suspected even though the BCF values of *P. purpureum* and *H. acutigluma* were high and were accumulators, but these two types of grass also had high TF values. This affects the value of phytoremediation. Reducing BCF values with high TF values causes a decrease in phytoremediation values. In *S. Spontaneum,* a low BCF value was offset by a TF value that was also low, so that the obtained phytoremediation value still exceeded the value of phytoremediation in *P. purpureum* and *S. spontaneum* (Figure 2.G and 2.H).

TF values can affect the value of phytoremediation, in this study the lowest TF values were found in *S. spontaneum* compared to *P. purpureum* and *H. acutigluma* (Figure 3.C). In addition to TF values, the factor that needs to be taken into account is the efficiency of Pb absorption, Efficiency of Pb absorption by grass. *S. spontaneum* was the highest compared to *P. purpureum* and species (Figures 2.G and 2.H), which would have a positive effect on the strength of phytoremediation.

Although lime causes grass to have a higher efficiency of Pb absorption compared to compost, the ability of phytoremediation of lime remains higher than compost. This is because the addition of compost causes better growth, so that it can increase the efficiency of Pb absorption, but the increased efficiency of Pb absorption due to composting has not been able to improve the ability of phytoremediation.

The application of compost to *P. purpureum*, *S. spontaneum* and *H. acutigluma* can lead to increased growth and efficiency of absorption of Pb in shoots and roots. this is because compost used is able to improve the chemical and microbiological properties of tailings and leads to increased growth and crop yield (Magnano et al. 2018). But the increase in growth due to composting was not followed by an increase in the concentration of root and shoot Pb. The concentration of Pb shoot and Pb root due to the administration of lime is higher than that of compost. So that the ability of phytoremediation is seen to be higher by giving lime than by compost. Grass that is given lime is seen to increase the concentration of Pb on the shoots and roots. It is suspected that grass with the addition of lime has a lower growth than if given compost, so that Pb concentration of heavy unity will be higher and affect the concentration of Pb in the weight of the plant.

In these three types of grass the growth of grass with high biomass will cause an increase in the efficiency of Pb absorption in the shoots and roots. The efficiency of Pb uptake from *S. spontaneum* was better than *P. purpureum* and *H. acutigluma*. This ability also contributes to the ability of phytoremediation. Although the ability of *S. spontaneum's* BCF ability was lower compared to *P. purpureum* and *H. acutigluma*, but *S. spontaneum* had a low TF value so that ultimately the phytoremediation ability of *S. spontaneum* remained higher than *H. acutigluma* and *P. purpureum.*

In addition to lime, the value of phytoremediation is higher than the addition of compost, while growth and efficiency of Pb absorption increase with the addition of compost. This is because the lime media has high BCF values and low TF values. So that it will cause a higher phytoremediation value. In this condition, the plant will retain more Pb in the roots and less Pb is translocated to the shoot.

Adding compost causes better grass growth (Magnano et al. 2018). It was also found in *P. purpureum*, *S. spontaneum* and *H. acutigluma* has grown in tailings media. Increasing growth in the type of grass will cause increased efficiency of Pb absorption in shoots and roots. However, the concentration of shoots of Pb and Pb root due to providing lime remained higher than compost.

According to Ashraf et al. (2011) plant metabolisms can influence the process of increasing Pb, so that at a better growth rate with improved Pb concentrations it is not necessarily able to increase shoot and root Pb concentrations because there are other factors such as plant metabolism which can also affect the ability of Pb absorption by roots and the translation is in the header.

The mechanism of phytoremediation that plants can do is phytoextraction and phytostabilization (Nascimento et al. 2014). Based on TF values <1, *S. Spontaneum*, *P. purpureum*, and *H. acutigluma* were assessed as phytostabilization. Where plants with high bioconcentration factors (BCF) and low translocation factors (TF) have the potential for phytostabilization (Yoon et al 2006).

The lowest TF value was found in *S. spontaneum* compared to *P. purpureum* and *H. acutigluma*. In addition to TF values, the factors that need to be improved are absorption efficiency, absorption efficiency by grass. *S. spontaneum* was the highest compared to *P. purpureum* and *H. acutigluma*, which had a positive effect on the strength of phytoremediation.

In this type of grass, the growth of grass with high biomass will increase the efficiency of Pb absorption in shoots and roots. The efficiency of Pb absorption by *S. spontaneum* also supports phytoremediation capabilities. The criteria used to select plants for phytoremediation such as short life cycles, wide distribution, large shoot biomass (Mazumdar and Das 2015), are also owned by *S. Spontaneum*. *S. Spontaneum* has a resistance to growing environments which are limited to nutrients and water, grows faster, high heavy metals, wider distribution, and larger biomass than *P. purpureum* and *H. acutigluma*.

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