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Phytoremediation with Acasia (*Acasia crassicarpa*) on peat soil using fly ash and dreg as ameliorants

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Abstract: Utilization of fly ash and dreg on peat soil to improve soil fertility is potential because there are large amount of fly ash and dreg as well as the existence of critical. This study was aimed to determine the effect of fly ash and dreg on the growth and the accumulation of metals Ba, Cd, Cr, Ni, Pb, and Se of *Acacia crassicarpa* and its absorption efficiency in the peat soil. The results showed that the addition of fly ash and dreg with different doses and different harvesting time influenced on the growth and the accumulation of heavy metals in *Acacia crassicarpa*. The results of the study also indicated that there were differences in the absorption efficiency of heavy metals by *Acacia crassicarpa*.

Keywords: fly ash, dreg, metal accumulation, absorption efficiency, *Acacia crassicarpa.*

Introductions

Burning coal and bark will produce a solid waste called fly ash. Research showed that fly ash can be used as a source of K, P, Ca, Mg, S, and some micro nutrients required by plants [1]. Addition of fly ash containing polyvalent cations Fe can bind organic acids and reduce toxic to plants. Based on the study which added fly ash soil and household waste (sewage sludge) at 1:1 (V/V) provides improved results on the growth of plants, so that the fly ash has the potential for use in the field of forestry [2].

Along with the increase in production capacity of the pulp and paper industry, there will be an increase in the amount of waste produced, including dreg. Dreg is a byproduct of the process of delignification in the pulp and paper industry. Dreg has pH 9, containing macro nutrients (P, K, Ca, Mg, and S) and micro nutrients (Cu, Co, and Mo) required for plant growth. Alternative utilization of fly ash and dreg for industrial forest is as ameliorant for peatland because the wastes contain K, Ca, Mg, P, and S used for plant growth. In addition, the wastes also contain polyvalent cations such as Fe that can potentially form a complex bond with organic acids.

In relation to the heavy metal content of Ba, Cd, Cr, Ni, Pb, and Se contained in fly ash and dreg, phytoremediation technology can be applied to reduce the content of heavy metals in the fly ash and dreg. Phytoremediation is contaminated land restoration technique using plants to absorb, degrade, transform and immobilize pollutants, both heavy metals and organic compounds. The technology is easy to apply, efficient, inexpensive and environmentally friendly [3], and the most efficient way to remediate soil near plant roots contaminant to a depth of 1 meter [4]. Therefore, phytoremediation is a technology that can be applied to extract the heavy metals in the fly ash and dreg.

In this study, the plant used for the remediation process was *Acacia crassicarpa*. This plant was easy to grow on a wide range of soils including poor soil fertility such as peat [5]. It was used in industrial forest pulp as a raw material for the manufacture of pulp and paper. Some *A. crassicarpa* plantations in Riau have been applying fly ash and dreg as ameliorant on peat but there has been no study of phytoremediation using this plant.

Materials and Methods

Materials and tools

Media soil used plant growth medium was peat soil from Nursery location of PT. Arara Abadi, and peat ameliorant consisted of fly ash and dreg. The other were *A. crassicarpa* with the age of 3 months, and the basic fertilizer consisted of urea and rock phosphate. The tools used including pots for growing plants, ruler, analytical balance, as a MS ICM heavy gauge metal.

Experimental design

This study used split plot design with completely randomized design pattern which consisted of three factors namely type of waste, waste dosage and time of harvesting. There were 2 levels of waste treatment, the doses level consisted of 5 treatments and harvesting time consisted of 2 treatment level, so from these three factors obtained 20 combinations. Each treatment combination was repeated three times. The design of treatment the type of waste as the main plot consists of fly ash and dreg, waste dose as a subplot; b1 = 0 g/pot, b2 = 25 g/pot ,b3 = 50 g/pot, b4 = 75 g/pot, b5 = 150 g/pot. Harvesting time as another plot consisted of 4 weeks and 8 weeks.

Variable

Research variables measured were: measurement of plant biomass by weighing the roots, stems and leaves of *A. crassicarpa* accumulation of heavy metals Ba, Cd, Cr, Ni, Pb and Se after harvesting, water absorbtion result of watering, the roots, stems and leaves of *A. crassicarpa*. Metal absorption efficiency can be calculated with the following equation:

$$\text{Efficiency absorption} = \frac{\text{Total heavy metals in plant}}{\text{Heavy metals in growing media}} \quad \text{(eq. 1)}$$

All the obtained data were analyzed by ANOVA (analysis of variance) at significant level ($\alpha = 0.05$).

Stages of research

Growing media

Each pot was filled with peat soil as much as 3 kg equivalent to the size of 2 mm. Furthermore, peat waste was given treatments at a dose of 0 g/pot, 25 g/pot, 50 g/ pot, 75 g/ pot, 150 g/pot. After all treatments mixed, media was subsequently watered until saturated or formed mud and then the mixture was incubated for 1 week to dissolve the interaction between waste and organic compounds in peat soil. 2.5 g of phosphate and 0.3 g of urea fertilizer was given 1 day before planting.

Planting seeds

A. crassicarpa was grown by the age of 3 months using the media and measured the initial height and diameter. A number of plants used in the study were 60 plants.

Plan maintenance

Watering was done 2 times a day in the morning and the afternoon with waste water of watering results fit into the bottle.

Harvesting

Harvesting was carried out carefully when the age of plants had been 4 and 8 months. The plants were washed and separated according to plant parts; roots, stems, and leaves, and measured for wet and dry weight. Each of the parts was analyzed for the content of Ba, Cd, Cr, Ni, Pb, and Se. Besides, remaining water in the bottom of the pots after 4 and 8 weeks planting was also analyzed of pH and of the accumulated Ba, Cd, Cr, Ni, Pb, and Se.

Results

pH and biomass of roots, stems, and leaves of *Acacia crassicarpa*

The type of ameliorants, doses, and harvesting time significantly affected plant's pH and biomass. The highest pH of media and water was reached after 4 weeks of harvesting time with the addition of dreg in the level of 150g/pot. The largest biomass of the roots was found in the treatment of fly ash with a dose of 25 g/pot and 8 weeks of harvesting time; the largest biomass of stems was obtained with the addition of 25 g/pot of fly ash and 8 weeks of harvesting time; while the addition of 25 g/pot of fly ash yielded the largest biomass of leaves (**Table 1**).

Accumulated Metals

Accumulated metals in the roots

Type of ameliorants, doses, and harvesting time significantly affected the accumulation of Ba, Cr, Ni, and Pb in the roots. The results of these treatments can be seen in **Table 2.**

Table 1. pH and biomass affected by type of ameliorants, doses, and harvesting time

Types of amelirants	Doses (g/pot)	Harvesting time (weeks)	pH		Biomass		
			media	water	roots	stems	leaves
Fly ash	0	4	5.67^{efg}	5.59^{de}	0.83^{g}	1.16^{bc}	2.67^{e}
	25		5.88^{ef}	4.81^{fg}	4.33^{d}	1.96^{bc}	6.73^{c}
	50		6.32^{d}	4.91^{fg}	5.16^{d}	2.73^{b}	4.40^{d}
	75		$5.38f^{g}$	4.57^{g}	1.83^{fg}	0.88^{bc}	2.40^{e}
	150		4.50^{h}	3.90^{h}	0.83^{g}	0.91^{bc}	2.63^{e}
	0	8	5.16^{g}	5.16^{ef}	0.91^{g}	1.29^{bc}	2.56^{e}
	25		4.55^{h}	4.81^{fg}	12.20^{a}	5.00^{a}	12.04^{a}
	50		5.91^{ef}	6.23^{c}	11.66^{a}	2.55^{bc}	5.30^{d}
	75		6.14^{cde}	6.03^{cd}	3.33^{e}	0.76^{c}	2.29^{e}
	150		6.76^{bc}	5.95^{cd}	3.26^{e}	0.70^{c}	2.46^{e}
Dreg	0	4	5.67^{efg}	5.67^{d}	0.83^{g}	1.16^{bc}	2.67^{e}
	25		6.42^{d}	6.42^{bc}	2.80^{ef}	1.00^{bc}	5.33^{d}
	50		7.24^{b}	6.23^{c}	$1. 00^{g}$	0.93^{bc}	3.21^{e}
	75		7.97^{a}	7.23^{a}	1.26^{g}	0.90^{bc}	2.38^{e}
	150		8.26^{a}	7.23^{a}	0.76^{g}	0.93^{bc}	2.34^{e}
	0	8	5.16^{g}	5.95^{cd}	0.91^{g}	1.29^{bc}	2.56^{e}
	25		6.05^{ef}	5.95^{cd}	10.66^{b}	5.00^{a}	8.00^{b}
	50		6.75^{bc}	6.08^{cd}	8.66^{c}	0.96^{bc}	2.36^{e}
	75		6.69^{bc}	6.69^{b}	2.96^{e}	0.85^{c}	2.30^{e}
	150		6.76^{bc}	6.03^{cd}	1.50^{g}	0.76^{c}	2.24^{e}

Note: Numbers in column followed by the same letter indicates no significant difference in the level of 95%

The biggest absorption of Ba was obtained with the addition of fly ash with a dose of 150 g/pot; the biggest uptake of Cr was obtained with the addition of dreg with a dose of 75 g/pot and 8 weeks harvesting time; the biggest uptake of Ni was obtained with the addition of dreg with a dose of 150g/ pot; while the largest Pb uptake in roots was mainly treated with dreg at a dose of 150 g/pot. All the highest uptake of heavy metal was reached in 8 weeks harvesting time.

Accumulated metals in the stems

Type of ameliorants, doses, and harvesting time significantly affected the accumulation of Ba and Cr in the stems but did not affect the accumulation of Cd, Ni, Pb, and Se (**Table 3**). The biggest accumulation of Ba was obtained with the addition of dreg ash with a dose of 150 g/pot and 8 weeks harvesting time. Whilst the biggest uptake of Cr was reached when added with fly ash with a dose of 150 g/ pot and 8 weeks harvesting time.

Accumulated metals in the leaves

All treatments of the type of ameliorants, doses, and harvesting time significantly affected the accumulation of Ba and Pb in leaves (**Table 4**). The biggest accumulation of Ba was obtained with the addition of dreg with a dose of 150g/pot and 8 weeks harvesting time, and the biggest accumulation of Pb in the stems was obtained with the addition of fly ash with a dose of 150g/pot and 8 weeks harvesting time.

Accumulated Efficiency of Metals

Results of analysis of variance showed a significant effect of type of ameliorants on the absorption efficiency of Ba, Ni, and Pb. While doses and harvesting time significantly affected the efficiency uptake of Ba, Cr, Ni, and Pb. Interactions of ameliorant types, doses, and harvesting time significantly affected the efficiency uptake of Ba, Cr, Ni, and Pb (**Table 5**).

The absorption efficiency of Ba performed by *A. crassicarpa* with the addition of fly ash was higher than the dreg at 4 and 8 weeks of harvesting time. The content of Cd and Se in the roots, stems, and leaves with treatments of type of ameliorants, doses, and harvesting time was very small with a range of values below the detection of heavy metal gauge which was below 1 mg/kg. On the other hand, the absorption efficiency of Cr, Ni, and Pb performed by *A. crassicarpa* with the addition of dreg was higher than fly ash either in 4 or 8 weeks of harvesting time. The order of metal absorption efficiency performed by *A. crassicarpa* with the addition of fly ash was Ba, Pb, Cr, and Ni, while the addition of dreg yielded Pb, Cr, Ni, and Ba respectively.

Table 2. The accumulation of Ba,Cd, Cr, Ni, Pb, and Se in the roots

Types of ameliorants	Doses (g/pot)	Harvesting time (weeks)	Accumulation metals in the roots					
			Ba	Cd	Cr	Ni	Pb	Se
Fly ash	0	4	4.96^{g}	0.0^{a}	0.50^{f}	0.50^{f}	0.50^{d}	0.0^{a}
	25		6.96^{g}	0.0^{a}	0.50^{f}	0.50^{f}	0.50^{d}	0.0^{a}
	50		5.96^{gh}	0.0^{a}	0.50^{f}	0.50^{f}	0.50^{d}	0.0^{a}
	75		9.03^{f}	0.0^{a}	1.00^{ef}	0.50^{f}	0.50^{d}	0.0^{a}
	150		12.03^{d}	0.0^{a}	2.00^{d}	1.03^{ef}	1.03^{d}	0.0^{a}
	0	8	5.03^{hi}	0.0^{a}	0.50^{f}	0.50^{f}	0.50^{d}	0.0^{a}
	25		10.03^{ef}	0.0^{a}	1.00^{ef}	0.50^{f}	1.03^{d}	0.0^{a}
	50		8.96^{f}	0.0^{a}	1.00^{ef}	0.50^{f}	1.06^{d}	0.0^{a}
	75		16.00^{bc}	0.0^{a}	1.06^{ef}	1.06^{ef}	3.00^{c}	0.0^{a}
	150		20.00^{a}	0.0^{a}	1.06^{ef}	2.06^{c}	2.96^{c}	0.0^{a}
Dreg	0	4	3.93^{i}	0.0^{a}	0.50^{f}	0.50^{f}	0.50^{d}	0.0^{a}
	25		3.96^{i}	0.0^{a}	3.00^{bc}	0.50^{f}	0.50^{d}	0.0^{a}
	50		4.16^{hi}	0.0^{a}	2.20^{cd}	1.46^{cde}	2.16^{c}	0.0^{a}
	75		5.20^{g}	0.0^{a}	3.13^{bc}	1.76^{cd}	2.96^{c}	0.0^{a}
	150		9.06^{f}	0.0^{a}	1.90^{de}	1.40^{de}	4.00^{b}	0.0^{a}
	0	8	3.96^{i}	0.0^{a}	0.50^{f}	0.50^{f}	0.50^{d}	0.0^{a}
	25		5.96^{gh}	0.0^{a}	2.23^{cd}	1.33^{de}	3.06^{c}	0.0^{a}
	50		10.16^{e}	0.0^{a}	3.23^{b}	3.76^{b}	4.13^{ab}	0.0^{a}
	75		15.30^{c}	0.0^{a}	5.00^{a}	3.30^{b}	4.93^{a}	0.0^{a}
	150		16.96^{b}	0.0^{a}	3.00^{b}	4.86^{a}	4.63^{ab}	0.0^{a}

Note: Numbers in column followed by the same letter indicates no significant difference in the level of 95%

Discussion

Fly ash and dreg are solid wastes from pulp and paper containing K, P, Ca, Mg, S and some micro nutrients required by plants and containing polyvalent cations can bind Fe organic acids. pH value, nutrients and heavy metals in the dreg were higher than in the fly ash except Fe. Provision of fly ash and dreg increased pH and content of Ba, Cr, Ni, and Pb in peat compared without the addition of ameliorant. The increase in pH could be caused by peat ameliorant reaction that produced OH- ions. CaO in the fly ash and dreg was soluble form of Ca $(OH)_2$ so that the reaction occured as follows:

$$CaO + H_2O \rightarrow Ca(OH)_2$$
$$Ca(OH)_2 \rightarrow Ca^{2+} + OH^-$$
$$OH^- + H^+ \rightarrow H_2O$$

The pH value and metal content in peat decreased with the increasing in harvesting time at all doses. The increasing doses of ameliorants yielded greater metal reduction in peat. The longer harvesting time and the higher dose, the greater peat decomposition process occurred so organic acids could be released which lowered pH of peat and dissolved metals. However, doses and harvesting time did not affect the content of Ba, Cd, Cr, Ni, Pb and Se in water splash.

Plant growth associated with the ability of plants to capture sunlight and convert ener-gy into carbohydrates in the process of pho-tosynthesis. It would affect the formation of plant tissues. High availability of nutrients that could be absorbed by plants would increase plant's photosynthesis process [6].

The addition of fly ash increased greater dry weight biomass of *A. crassicarpa* than dreg. This is due to the high content of polyvalent cations Fe and a balance of nutrients in the fly ash. Fe can bind to organic acids in peat forming complex compounds and is able to suppress the solubility of the organic acid, thereby reducing toxic to plants. Polyvalent cation complex bond with organic compounds also formed negatively charged functional groups capable of binding water so that the fly ash can absorb more water than dreg. Other studies have reported that administration of Al, Fe, and Cu cations cause changes in the physical properties of peat due to the damage to the structure of humic and fulvic acids [7] and increase the bulk density, lower porosity of the fiber pores drainage [8].

Use of *A. crassicarpa* was able to reduce levels of Ba, Cr, Ni, and Pb in soil, especially at harvest time 8 weeks. Absorption and accumulation metals by plants can be divided into three processes are continuous, in metal uptake by root, metal translocation from roots to other plant parts, and metal on the localization of certain cells to keep the plant does not inhibit metabolism [9].

The accumulation efficiency of Ba, Cd, Ni, and Pb which was performed by *A. crassicarpa* tended to increase along the length of harvesting time. This situation shows that an increase in the length of time of harvest did not inhibit the efficiency of absorption by plants. In fly ash, a sequence of metal uptake efficiency by *A. crassvzicarpa* was Ba, Pb, Cr and Ni, while in the dreg was Pb, Cr, Ni, and Ba. The larger the atomic weight, the higher the uptake efficiency. The order of metal uptake efficiency was strongly influenced by the atomic weight of each element. The larger the atomic weight the higher the efficiency [10].

Table 3. The accumulation of Ba,Cd, Cr, Ni, Pb, and Se in the stems

Types of ameliorants	Doses (g/pot)	Harvesting time (weeks)	Accumulation metals in the stems					
			Ba	Cd	Cr	Ni	Pb	Se
Fly ash	0	4	2.00^{g}	0.0^{a}	0.50^{e}	0.0^{a}	0.0^{a}	0.0^{a}
	25		2.00^{g}	0.0^{a}	0.50^{e}	0.0^{a}	0.0^{a}	0.0^{a}
	50		1.96^{g}	0.0^{a}	0.50^{e}	0.0^{a}	0.0^{a}	0.0^{a}
	75		2.00^{g}	0.0^{a}	0.50^{e}	0.0^{a}	0.0^{a}	0.0^{a}
	150		2.03^{g}	0.0^{a}	0.50^{e}	0.0^{a}	0.0^{a}	0.0^{a}
	0	8	2.03^{g}	0.0^{a}	0.50^{e}	0.0^{a}	0.0^{a}	0.0^{a}
	25		1.96^{g}	0.0^{a}	0.50^{e}	0.0^{a}	0.0^{a}	0.0^{a}
	50		2.00^{g}	0.0^{a}	1.00^{de}	0.0^{a}	0.0^{a}	0.0^{a}
	75		2.00^{g}	0.0^{a}	2.03^{b}	0.0^{a}	0.0^{a}	0.0^{a}
	150		2.00^{g}	0.0^{a}	3.03^{a}	0.0^{a}	0.0^{a}	0.0^{a}
Dreg	0	4	2.03^{g}	0.0^{a}	0.50^{e}	0.0^{a}	0.0^{a}	0.0^{a}
	25		12.00^{f}	0.0^{a}	0.50^{e}	0.0^{a}	0.0^{a}	0.0^{a}
	50		22.50^{e}	0.0^{a}	0.50^{e}	0.0^{a}	0.0^{a}	0.0^{a}
	75		37.66^{cd}	0.0^{a}	1.43^{cd}	0.0^{a}	0.0^{a}	0.0^{a}
	150		41.66^{c}	0.0^{a}	1.60^{bc}	0.0^{a}	0.0^{a}	0.0^{a}
	0	8	1.93^{g}	0.0^{a}	0.50^{e}	0.0^{a}	0.0^{a}	0.0^{a}
	25		15.00^{f}	0.0^{a}	0.50^{e}	0.0^{a}	0.0^{a}	0.0^{a}
	50		32.33^{d}	0.0^{a}	0.50^{e}	0.0^{a}	0.0^{a}	0.0^{a}
	75		48.80^{b}	0.0^{a}	1.63^{bc}	0.0^{a}	0.0^{a}	0.0^{a}
	150		90.50^{a}	0.0^{a}	2.06^{b}	0.0^{a}	0.0^{a}	0.0^{a}

Note: Numbers in column followed by the same letter indicates no significant difference in the level of 95%

Table 4. The accumulation of Ba, Cd, Cr, Ni, Pb, and Se in the leaves

Types of ameliorants	Doses (g/pot)	Harvesting time (weeks)	Accumulation metals in the leaves					
			Ba	Cd	Cr	Ni	Pb	Se
Fly ash	0	4	0.83^{i}	0.0^{a}	0.0^{a}	0.0^{a}	0.50^{c}	0.0^{a}
	25		1.00^{i}	0.0^{a}	0.0^{a}	0.0^{a}	0.50^{c}	0.0^{a}
	50		1.96^{gh}	0.0^{a}	0.0^{a}	0.0^{a}	0.50^{c}	0.0^{a}
	75		2.03^{h}	0.0^{a}	0.0^{a}	0.0^{a}	0.50^{c}	0.0^{a}
	150		2.00^{gh}	0.0^{a}	0.0^{a}	0.0^{a}	0.50^{c}	0.0^{a}
	0	8	0.83^{i}	0.0^{a}	0.0^{a}	0.0^{a}	0.50^{c}	0.0^{a}
	25		2.00^{gh}	0.0^{a}	0.0^{a}	0.0^{a}	0.50^{c}	0.0^{a}
	50		3.03^{f}	0.0^{a}	0.0^{a}	0.0^{a}	0.50^{c}	0.0^{a}
	75		7.00^{c}	0.0^{a}	0.0^{a}	0.0^{a}	0.50^{c}	0.0^{a}
	150		8.03^{b}	0.0^{a}	0.0^{a}	0.0^{a}	0.50^{c}	0.0^{a}
Dreg	0	4	1.00^{i}	0.0^{a}	0.0^{a}	0.0^{a}	0.50^{c}	0.0^{a}
	25		1.18^{hi}	0.0^{a}	0.0^{a}	0.0^{a}	0.50^{c}	0.0^{a}
	50		2.10^{h}	0.0^{a}	0.0^{a}	0.0^{a}	0.50^{c}	0.0^{a}
	75		3.33^{f}	0.0^{a}	0.0^{a}	0.0^{a}	0.50^{c}	0.0^{a}
	150		6.00^{d}	0.0^{a}	0.0^{a}	0.0^{a}	1.40^{b}	0.0^{a}
	0	8	0.96^{i}	0.0^{a}	0.0^{a}	0.0^{a}	0.50^{c}	0.0^{a}
	25		2.70^{fg}	0.0^{a}	0.0^{a}	0.0^{a}	0.50^{c}	0.0^{a}
	50		4.60^{e}	0.0^{a}	0.0^{a}	0.0^{a}	0.50^{c}	0.0^{a}
	75		7.13^{c}	0.0^{a}	0.0^{a}	0.0^{a}	1.46^{b}	0.0^{a}
	150		9.00^{a}	0.0^{a}	0.0^{a}	0.0^{a}	2.30^{a}	0.0^{a}

Note: Numbers in column followed by the same letter indicates no significant difference in the level of 95%

Table 5. The absorbtion efficiency of Ba, Cd, Cr, Ni, Pb, and Se.

Types of ameliorants	Doses (g/pot)	Harvesting time (weeks)	Efficiency (%)					
			Ba	Cd	Cr	Ni	Pb	Se
Fly ash	0	4	0.003^{g}	$0,0^{a}$	0.00^{g}	0.00^{c}	0.00^{g}	$0,0^{a}$
	25		0.07^{cde}	$0,0^{a}$	0.00^{g}	0.00^{c}	0.00^{g}	$0,0^{a}$
	50		0.02^{fg}	$0,0^{a}$	0.00^{g}	0.00^{c}	0.00^{g}	$0,0^{a}$
	75		0.02^{fg}	$0,0^{a}$	0.01^{g}	0.00^{c}	0.00^{g}	$0,0^{a}$
	150		0.02^{fg}	$0,0^{a}$	0.02^{g}	0.01^{bc}	0.01^{fg}	$0,0^{a}$
	0	8	0.003^{g}	$0,0^{a}$	0.00^{g}	0.00c	0.00^{g}	$0,0^{a}$
	25		0.37^{a}	$0,0^{a}$	0.11^{cd}	0.00^{c}	0.25^{c}	$0,0^{a}$
	50		0.15^{b}	$0,0^{a}$	0.10^{cde}	0.00^{c}	0.13^{def}	$0,0^{a}$
	75		0.08^{cd}	$0,0^{a}$	0.04^{efg}	0.03^{bc}	0.12^{def}	$0,0^{a}$
	150		0.09^{c}	$0,0^{a}$	0.09^{cde}	0.05^{bc}	0.11^{defg}	$0,0^{a}$
Dreg	0	4	0.006^{g}	$0,0^{a}$	0.00^{g}	0.00^{c}	0.00^{g}	$0,0^{a}$
	25		0.02^{fg}	$0,0^{a}$	0.14^{c}	0.00^{c}	0.00^{g}	$0,0^{a}$
	50		0.02^{fg}	$0,0^{a}$	0.03^{fg}	0.03^{bc}	0.07^{defg}	$0,0^{a}$
	75		0.023^{fg}	$0,0^{a}$	0.05^{def}	0.03^{bc}	0.07^{defg}	$0,0^{a}$
	150		0.02^{fg}	$0,0^{a}$	0.04^{fg}	0.01^{bc}	0.10^{defg}	$0,0^{a}$
	0	8	0.01^{g}	$0,0^{a}$	0.00^{g}	0.00^{c}	0.00^{g}	$0,0^{a}$
	25		0.08^{cd}	$0,0^{a}$	0.37^{a}	0.25^{a}	0.51^{a}	$0,0^{a}$
	50		0.09^{c}	$0,0^{a}$	0.21^{b}	0.29^{a}	0.39^{b}	$0,0^{a}$
	75		0.05^{def}	$0,0^{a}$	0.14^{c}	0.11^{b}	0.19^{cd}	$0,0^{a}$
	150		0.04^{ef}	$0,0^{a}$	0.09^{cde}	0.09^{bc}	0.14^{cde}	$0,0^{a}$

Note: Numbers in column followed by the same letter indicates no significant difference in the level of 95%

Conclusion

Provision of fly ash and dreg significantly affected the growth of *A. crassicarpa* and its efficiency of metal uptake. Mostly heavy metals were accumulated in the roots and the largest uptake efficiency was at the plant roots.

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