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The Use of Fly Ash in Peat Soil on the Growth and Yield of Rice

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ABSTRACT

The research aims to study the use of fly ash for improving the growth and yield of rice in peatland. The peat soil material that used in this study was sapric weathering level. The field research was designed by using a completely randomized design. The treatment in this study was the application of fly ash consisting of six levels (0, 25, 50, 75, 100 and 125 g fly ash per pot), each treatment repeated 4 times. The results showed that the best plant growth and yield of rice were gained from the application of fly ash at the lower dose (25 g pot⁻¹ and 75 g pot⁻¹, respectively). The increase in fly ash dose (100 g pot⁻¹ and 125 g pot⁻¹) did not gave the highest rice yield (9.67% and 0.2% lower than the dose of 75 g pot⁻¹) due to the macronutrients N, P and K as a limiting factor (only as a basic fertilizer).

INTRODUCTION

Low fertility of peat soils inhibits plant growth. This condition is indicated by very low availability of macronutrients (N, P, K, Ca, Mg and P) and micronutrients (Fe, Cu, Zn, Mn and Mo), as well as low soil pH, and base saturation (BS). In contrast, cation exchange capacity (CEC) is high (Nelvia, 2014; Simbolon, 2009; Tim Sintesis Kebijakan, 2008); and high organic acid content, especially the phenolic acids, which have phytotoxic effect for crops plant (Maftuah & Indrayati, 2014; Simbolon, 2009). The peat soil Gunung Makmur East Kalimantan has low pH and BS, moderate total N but CEC, P and K available were high (Rusdiansyah & Saleh, 2017). These conditions cause plant growth in peat soil to be hampered, as consequence decreases of plant productivity. About 60% of rice production in South Sumatra comes from tidal swamps, but its productivity is very low at around 3.5 t ha⁻¹ (Sulistiyani, 2013). The growth of rice plants on peatlands that have thickness above 2 m is hampered and fails to fill the grain (Tim Sintesis Kebijakan, 2008). Rice is a main staple food in Asia especially in Indonesia, so it is one of the factors that can threaten food sustainability and increase poverty. Therefore, Indonesia must increase national rice production by increasing rice productivity (Effendi AR, Anwar, & Mayerni, 2018). Increasing of rice productivity in peat soil should add material with

a high nutrient content, like fly ash.

In Riau Province, there is a lot of agro-industry, including pulp and paper industry. Increased production capacity of the pulp and paper industry is followed by the high amount of waste or by-products, including boiler ash (fly ash). Up to ± 5% fly ash can be recovered out of the total waste materials burned (Borhan, Ismail, & Rahmat, 2010). Fly ash is generated from coal, piece of wood and bark combustion process at high temperatures. The results of several studies show that fly ash potentially used as a organic fertilizer due to they contain nutrients (i.e P, K, Ca, Mg, S, Fe, Cu, Zn and Mn) required by plant. The main components of the fly ash fine particles comprise alumina (Al₂O₃) and silica (SiO₂) and the other components consist of sodium oxide (Na₂O), potassium oxide (K₂O) and iron oxide (Fe₂O₃) (Kim, Yoon, & Park, 2014). According to Chan, Mazlee, Ahmad, Ishak, & Shamsul (2017) the chemical composition of fly ash consists of (wt%) Al₂O₃ (20.70%), SiO₂ (40.40%), K₂O (1.88%), CaO (13.50%), TiO₂ (4.85%), Fe₂O₃ (11.80%), MnO (0.13%) and CuO (0.13%). Panda, Mishra, Muduli, Nayak, & Dhal (2015) reported that fly ash as residue of coal burning consisted of oxides of Al, Fe, Si and Ca i.e. around 95-99% and Na, P, K and S about 0.5–3.5% and several essential elements such as Zn, Fe, Mn, B and Mo. Wood ash contains of macronutrients such as P, K, Ca, Mg, Mn and micronutrients Fe, Cu, Zn,

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Mn, Mo and B (Scheepers & du Toit, 2016). According to Basu, Pande, Bhadoria, & Mahapatra (2009) and Rejeki, Nelvia, & Saryono (2014), fly ash of the pulp and paper industry contains macronutrients such as P, K, Ca, Mg, S and micronutrients (e.g Fe, Zn, Cu, Co, B and Mo). Fly ash as residue of shells and fibers combustion process contain macronutrients such as N, P, K, Ca, Mg, S and micronutrients such as Fe, Mn, Cu, and Zn (Mulyani, Suryaningtyas, Suwardi, & Suwarno, 2016).

The pH of fly ash is strong alkaline (pH 10-13.3) (Rejeki, Nelvia, & Saryono, 2014) which means that it has a strong liming effect. Fly ash also contains non-essential elements (heavy metals) such as Ni, Cr, Pb (Panda, Mishra, Muduli, Nayak, & Dhal, 2015) and also contains Cd, As, Hg, V, As and Ba (Rejeki, Nelvia, & Saryono, 2014), but the levels are very low so it can be used as a soil ameliorant, especially for peat soil. Fly ash can be used to fertilize soil namely improve physical, chemical and biological properties of soil, as well as to enhance the crop productivity, depending upon the nature of soil and fly ash (Sharma & Kalra, 2006). The use of fly ash as a peat soil ameliorant has a twofold effect. Firstly, it facilitates the return of nutrients to the soil ecosystem in increasing soil pH and decreasing concentration of phenolic acid. Secondly, it helps to utilize fly ash generated as a by-product of combustion of wood, coal, bark, sawdust whether for heat or power generation. Fly ash can be used as a fertilizer to improve soil fertility and soil pH. The formation of complex compounds (chelate) between organic acids of peat soil with polyvalent cations such as Al, Fe, Cu, Zn and Mn can increase peat soil stability and decrease organic acids solubility, so that the bad effects can be reduced. The stability of complexes among humic acid-metal is getting weaker respectively $Al^{3+} > Fe^{3+} > Cu^{2+} > Mn^{2+} > Zn^{2+} > Mg^{2+} > Ca^{2+}$ (Tan, 2014).

The addition of fly ash can improve the characteristic of chemistry, physics and biology of peat soil. The use of fly ash in peat soil can increase soil pH and improve soil fertility because can increase nutrients availability required for plant growth such as P, K, Ca, Mg, S, Fe, Cu, Zn, Mn, B and Mo and increase population of microb so that stimulate the decomposition of peat and release of N so increasing its availability (Sharma & Kalra, 2006). Decomposition is a process to meet energy requirements for decomposers, while biological activity is supported by appropriate soil physical and chemical conditions, such as soil moisture,

pH, substrate as a source of energy and nutrients (Djajakirana, Puspasari, Permatasari, Soesanto, & Maria, 2012). The concentration of organic acids in peat is very high so it is toxic to plants. Organic acids react with metal ions of Fe, Al, Cu, Zn and Mn which dissolve from fly ash to form complex organic metal compounds so as to suppress their solubility. Chan, Mazlee, Ahmad, Ishak, & Shamsul (2017) report that fly ash can improve soil physical properties such as decreasing density particles and porosity. The particle density reduced caused by the presence of highly fly ash content in porous composites. The fly ash have closed the internal pores and increased density of samples.

Fly ash can be used to increase the yield of many agricultural crops. Experts from several countries reported that the fly ash had the potential to fix the properties of peat soil in increasing crop production (Björk et al., 2010; Ernfors, Sikström, Nilsson, & Klemetsson, 2010). The application of rice husk ash brick factory residue which is enriched by N, P and K fertilizers in rainfed Vertisol soil increased grain (rice) production both quality and quantity of (Suwanto, Sutrisno, & Suryono, 2015). The plant grows very well on the former land of the fly ash landfill. Rejeki, Nelvia, & Saryono (2014) reported that the addition of fly ash dosage of 50-75 g pot⁻¹ increased weight of plant biomass and pH of peat soil. Plant growth of rice and maize were mostly enhanced in the treatments with 20-40% fly ash, being optimal at 60%, from 80% onwards the measured parameters tended to decrease (Panda, Mishra, Muduli, Nayak, & Dhal, 2015). The application of fly ash at 50 t ha⁻¹ increased the yield of cereal crops from 5-20%, vegetable crop from 5-20%, plantation crops from 20-30%, rice crop 13-17%, sugarcane crop from 15-30%, maize crop from 36-40% and potato crop from 25-37% over control (Arivazhagan et al., 2011). The use of fly ash in peatlands to improve the growth and yield of rice has not been widely reported. The research aims to study the effect of use of fly ash in the peat soil on the growth and yield of rice and get a dose of fly ash which resulted the good growth and high yield of rice in the peat soil. The growth and yield of rice in peat soils is thought to increase with the increases of dose of fly ash.

MATERIALS AND METHODS

This research was conducted at the green house of the Agriculture Faculty of University of Riau from July to October 2012. Chemical properties of

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peat soils materials and fly ash were analyzed at laboratory of Soil Research, Bogor. The material of peat soil with weathering sapric was collected at 0 to 30 cm depth from Kerumutan village, Pelalawan and while fly ash was taken from pulp and paper industry at Perawang, Riau. Analysis of chemical characteristics of peat soil before the experiment indicated the following details i.e.: pH (pH meter), base saturation and CEC ($1 \text{ N NH}_4\text{OAc pH 7.0}$), organic C (Walkley and Black), total N (Kjeldahl), the ratio of C/N, available P_2O_5 (Bray⁻¹), total P_2O_5 (HCl 25%), exchangeable bases (K, Ca, Mg and Na) ($1 \text{ N NH}_4\text{OAc pH 7.0}$), available micronutrients (Fe, Cu, Zn and Mn) (DTPA), the total micronutrients (Fe, Cu, Zn and Mn) ($\text{HClO}_4\text{p.a} + \text{HNO}_3\text{p.a}$ =pro analysis) and ash content (gravimetry). Analysis of chemical properties of peat soil after a month incubation with fly ash were pH (H_2O), P-Bray⁻¹ and total P, K, Ca, Mg, Fe, Zn and Cu ($\text{HClO}_4\text{p.a} + \text{HNO}_3\text{p.a}$). Analysis of chemical characteristics of fly ash i.e.: pH (pH meter), total of macronutrients (P, K, Ca, Mg, Na and S) and micronutrients (Fe, Cu, Zn and Mn) ($\text{HClO}_4\text{p.a} + \text{HNO}_3\text{p.a}$) and available nutrients (2% citric acid) and moisture content (oven dried 105°C). The experimental design was a completely randomized design. The treatment in this study was the addition of fly ash consisting of six levels: 0, 25, 50, 75, 100 and 125 g fly ash per pot (0, 5, 10, 15, 20 and 25 t ha^{-1}), each treatment repeated 4 times with rice plant as the plant indicator was IR-64.

Media seedlings were 2 kg of peat soil mixed with 25 g fly ash and incubated for 1 month. At the end of the incubation they were given NPK fertilizer doses of 0.8 g N, 0.27 g P_2O_5 and 0.45 g K_2O per pot (160 kg N, 54 kg P_2O_5 and 90 kg K_2O ha^{-1}) respectively. The seeds were soaked for 48 hours before sowing. At the end of the incubation, soil chemical properties were analyzed to determine the chemical properties of peat soil. Rice seedlings were planted in pots containing 2 kg of peat soil mixed with fly ash and had been incubated for 1 month. NPK fertilizer were dose of 0.8 g N ($\frac{1}{2}$ dose), 0.27 g P_2O_5 and 0.45 g K_2O per pot, and $\frac{1}{2}$ dose of N (0.8 g N per pot) was given after 30 days. Each pot was planted 5 seedlings until 21 days, then only 3 tillers were maintained up to harvest. Dosages of fly ash and fertilizer were calculated based on the weight of the sapric peat soil with the assumption that 1 ha of soil weight was 400000 kg with bulk density (BD) 0.2 g cm^{-3} .

The observed parameters were plant height, maximum tillers number and panicles number, weight

of dry straw, emerged flowers age, weight of 1000 grain and yield of rice. Data were analyzed by using paired t test to know significant differences between with and without fly ash on incubation research. Data parameters of growth and yield statistically analyzed by using analysis of variance, followed by DMRT at $P < 0.05$ and correlation between parameters measured by Pearson correlation test.

RESULTS AND DISCUSSION

Chemical Characteristic of the Fly Ash

The laboratory analysis showed that the fly ash pH was very high, macronutrients and micronutrients content were getting lower in the order of respectively $\text{Ca} > \text{K} > \text{Mg} > \text{S} > \text{P}$ and $\text{Fe} > \text{Mn} > \text{Zn} > \text{Cu}$ (Table 1). The macro and micronutrients contained in fly ash were quickly available in peat. Fly ash was hydrolyzed by ion H^+ so that it dissolved quickly. The concentration of H^+ ion on peat soil was very high because H^+ ion was dissociated from organic compounds. The extraction result by using citric acid 2% was almost equal to extraction result with HClO_4 and HNO_3 , it meant fly ash dissolved easily. Therefore the fly ash potentially used to increase nutrient availability for supporting plant growth.

Chemical Characteristic of Peat Soil before and after Fly Ash Application

Prior to fly ash application, the peat soil had low soil pH, in contrast available P and total P were very high and the ash content was high (Table 2). Total N content and organic C were high and the C/N ratio was very high. Even though the total N was high, but C/N ratio was very high, indicated that N is not mineralized yet. It caused N availability for plant was very low, so N a limiting factor for plant growth. Cation value of CEC was very high, but base saturation was very low, so that it could inhibit the mobilization of nutrients, mainly K, Ca and Mg. It inhibited the growth plant and decreased production of plant. The availability and total of micronutrients (Cu, Zn and Mn) were very low except for Fe which was quite high causing deficiency at plants. Tim Sintesis Kebijakan (2008) and Simbolon (2009) reported that the chemical characteristics of peat soil such as pH and base saturation were very low and the available macronutrients (N, P, K, Ca and Mg) and micronutrients (Cu, Zn, Mn, Fe, B and Mo) were also low, but CEC was very high. The peat soil from Banjar, South Kalimantan had a very low fertility with very low pH (3.19), the nutrient content of N, P, K was very low as well (Maftuah & Indrayati, 2014).

Table 1. Chemical characteristics and moisture of fly ash

Chemical characteristics	Value	Chemical characteristics	value
pH H ₂ O (1:5)	12.00	Moisture (%)	14.36
Macronutrient Total		Macronutrient available	
P ₂ O ₅ (%)	0.36	P ₂ O ₅ (%)	0.30
K ₂ O (%)	0.99	K ₂ O (%)	0.76
CaO (%)	6.67	CaO (%)	6.10
MgO (%)	0.82	MgO (%)	6.00
Na (%)	0.23	Na (%)	0.21
S (%)	0.58	S (%)	0.36
Micronutrient Total		Micronutrient available	
Fe (%)	1.90	Fe (%)	1.37
Mn (ppm)	452.00	Mn (ppm)	297.00
Cu (ppm)	26.00	Cu (ppm)	14.00
Zn (ppm)	48.00	Zn (ppm)	10.00
Heavy metal Total		Heavy metal available	
Pb (ppm)	13.50	Pb (ppm)	0.20
Cd (ppm)	0.90	Cd (ppm)	nm
As (ppm)	4.20	As (ppm)	nm
Hg (ppm)	0.13	Hg (ppm)	nm
Co (ppm)	6.70	Co (ppm)	6.70
Ni (ppm)	42.60	Ni (ppm)	42.60
Cr (ppm)	61.40	Cr (ppm)	61.40
Ag (ppm)	6.00	Ag (ppm)	6.00
Sn (ppm)	nm	Sn (ppm)	nm

Remarks: nm = not measurable

Table 2. Chemical characteristics and ash content of peat soil

Chemical properties of peat soil and ash content	Value	Category
pH H ₂ O (1:5)	3.20	very low
pH KCl (1:5)	3.00	very low
organic-C (%)	4.373	high
Total N (%)	0.065	high
C/N ratio	67.28	very high
Available P ₂ O ₅ Bray-1 (ppm)	135.40	very high
Total P ₂ O ₅ (ppm)	320.00	very
Exchangeable Cation		
Ca (me 100 g ⁻¹)	2.27	very low
Mg (me 100 g ⁻¹)	0.68	very low
K (me 100 g ⁻¹)	0.22	very low
Na (me 100 g ⁻¹)	0.26	very low
CEC (me 100 g ⁻¹)	72.45	very high
Base Saturation (%)	6.00	low
Micronutrient available		
Fe (ppm)	475.00	high
Mn (ppm)	1.00	very low
Cu (ppm)	2.00	very low
Zn (ppm)	2.00	very low
Micronutrient Total		
Fe (%)	0.36	high
Mn (ppm)	12.30	very low
Cu (ppm)	3.10	very low
Zn (ppm)	4.80	very low
Ash content (%)	15.89	high

Table 3. The effect of the application of fly ash after incubated for one month on chemical characteristics of peat soil

Chemical characteristics of peat soil	Dose of fly ash	
	0 g pot ⁻¹	25 g pot ⁻¹
pH H ₂ O (1:5)	3.30 ^a	4.22 ^a
Available P ₂ O ₅ Bray-1 (ppm)	24.39 ^b	279.55 ^a
Macronutrient Total		
P ₂ O ₅ (ppm)	273.33 ^a	754.33 ^a
K (%)	0.04 ^a	0.15 ^a
Ca (%)	0.06 ^a	0.34 ^a
Mg (%)	0.04 ^a	0.08 ^a
Micronutrient Total		
Fe (%)	0.319 ^a	1.237 ^a
Mn (ppm)	15.96 ^b	228.64 ^a
Cu (ppm)	3.87 ^b	18.64 ^a
Zn (ppm)	4.35 ^b	17.35 ^a

Remarks: The numbers in the same rows which followed the same lowercase letter are not significantly different at P < 0.05 t test

Application of fly ash 25 g pot⁻¹ (2 kg peat soil) after incubated for a month increased the soil pH about 0.49 unit and nutrients essential of peat soil i.e: available P, total P, K, Ca, Mg, Fe, Mn, Cu and Zn about 11, 2.76, 3.75, 5.67, 2.387, 14.32, 4.82 and 3.98 times respectively compared to without fly ash (Table 3). This result correspond to the result

of Sharma & Kalra (2006) who reported that the addition of fly ash on peat soils increased soil pH and nutrients availability required for plant growth. Another research conducted by Maftuah & Indrayati (2014) reported the treatment of biochar could increase soil pH, total N, and available P though it was not significant and significant in increasing the exchangeable K compared to controls.

The use of fly ash dose of 25 g pot⁻¹ increased plant growth significantly compared to without fly ash, but at a dose of 75 g pot⁻¹ the increase was higher. The height of plant, maximum tillers number, panicles number and dry straw weight at a dose of 75 g pot⁻¹ increased by 18.57 cm, 153%, 102% and 99%, respectively compared to without fly ash. At a higher dose of fly ash (100 g pot⁻¹ and 125 g pot⁻¹) the increased the panicles number (107% and 116%, respectively) and the dry straw weight (144% and 113%, respectively) higher than a dose 75 g pot⁻¹ (Table 4). Fly ash application on peat soil, in addition to increasing the essential nutrients such as P, K, Ca, Mg, Fe, Mn, Cu and Zn in the soil (Table 3), may

also increase the S, Si, B and Mo in soil, because fly ash contains macro nutrients, micronutrients and Si required by plant (Chan, Mazlee, Ahmad, Ishak, & Shamsul, 2017; Panda, Mishra, Muduli, Nayak, & Dhal, 2015; Scheepers & du Toit, 2016). The higher the dose of fly ash added to the peat soil, the greater the contribution in increasing the availability of nutrients for plants so that the greater the effect on plant growth.

Fly ash as well as act as a soil conditioner, because in addition to improving essential nutrients, also can improving soil pH of the peat soil. Purwati, Soetopo, & Setiawan (2007) reported that the use of fly ash dose of 10 kg tree⁻¹ or 10 t ha⁻¹ per period of planting could improve chemistry, physics and biology of peat soil. According to Basu, Pande, Bhadoria, & Mahapatra (2009), Sharma & Kalra (2006), Scheepers & du Toit (2016), the use of fly ash increased pH value and concentration of nutrients (P, K, Ca, Mg, S, Fe, Cu, Zn, Mn, B and Mo) available to plants. The use of fly ash can stimulate the decomposition of peat and release of N.

Table 4. The effect of the application of fly ash in peat soils on the height of plant, maximum tillers number, panicles number and dry straw weight

Fly ash (g pot ⁻¹)	Height of plant (cm)	Maximum tillers number (tillers pot ⁻¹)	Panicles number (panicles pot ⁻¹)	Dry straw weight (g pot ⁻¹)
0	49.90 ^c	16.33 ^c	14.33 ^b	21.42 ^e
25	59.20 ^b	38.68 ^{ab}	26.67 ^a	38.69 ^d
50	57.40 ^b	41.67 ^{ab}	26.00 ^a	42.37 ^{cd}
75	68.47 ^a	41.33 ^{ab}	29.00 ^a	42.70 ^{cd}
100	65.70 ^a	47.33 ^a	29.68 ^a	52.36 ^{abc}
125	69.57 ^a	38.33 ^{ab}	31.00 ^a	45.82 ^{bcd}

Remarks: The numbers in the same columns which followed the same lower case letter did not significantly different at P < 0.05 DMR test

Table 5. The effect of the use of fly ash in peat soils on the age emerged panicle, weight of 1000 grains and yield of rice

Fly ash (g pot ⁻¹)	Age emerged panicle (day after planting)	Weight of 1000 grains (g)	Yield of rice (g pot ⁻¹)
0	64.67 ^a	22.30 ^c	24.71 ^{cd}
25	62.33 ^a	23.14 ^{bc}	40.54 ^{abc}
50	64.33 ^a	24.45 ^{abc}	41.09 ^{abc}
75	62.33 ^a	25.80 ^a	50.15 ^{ab}
100	64.33 ^a	24.27 ^{abc}	45.03 ^{ab}
125	60.33 ^{ab}	24.87 ^{ab}	50.05 ^{ab}

Remarks: The numbers in the same columns followed by the same lowercase letter did not significantly different at P < 0.05 DMR test

Table 6. Correlation between variable panicles number, age emerged panicle, weight of 1000 grains, dry weight of rice straw, and yield of rice

Variable of growth and yield	Age emerged panicle	Weight of 1000 grains	Dry straw weight	Yield of rice
Panicles number	-0.564**	0.807**	0.941**	0.969**
Age emerged panicle		-0.450*	-0.301ns	-0.628**
Weight of 1000 grains			0.731**	0.903**
Dry straw weight				0.871**

Remarks: Pearson correlation test: ns = non significant; * = significant at $p < 0.05$; ** = significant at $p < 0.01$

The improvement of chemical characteristic of peat soil was indicated by the high macro and micro nutrients availability, pH, and base saturation, as well as the low CEC and concentration of organic acid, especially the phenolic acids so have not poison for plant. This improvement caused a better root environment. This condition encourage root growth and increase root volume, so the water and nutrients was highly uptaked by plants. Furthermore, it promotes processes of physiology (such as photosynthesis) and metabolism of rice plants. Macronutrients such as C, H, O, N and Mg with micronutrients Cu and Fe formed chlorophyll. Element of C, H, O, N and S or without S formed amino acid, amino acids served to form proteins and Ca contributed to form the structure middle lamella of cell wall of plant. Micronutrients like Fe, Cu, Zn, Mn, B and Mo also played a role in the formation of protein. Protein acted as a catalyst for some reactions of metabolism and as a components of the cell nucleus (Hawkesford et al., 2012). The cell nucleus consists of protein, the formation of new cells is initiated by the division of plant cell nucleus. The cleavage of nucleus of cells means that the formation of new cells/tissue or plant growth. The increasing of physiology and metabolism processes stimulate the plant growth which is shown by the increasing of plant height, maximum tillers number, panicles number and dry weight of straw. YosefTabar (2013) reported that the application of N and P fertilizer resulted increases in the number of maximum tillers and productive tillers. The application of biochar as ameliorant on peat soil could increase plant height, the number of maximum tillers and the number of panicles of rice compared to controls (Maftuah & Indrayati, 2014). Panda, Mishra, Muduli, Nayak, & Dhal (2015) reported that the use of fly ash 20-40% increased plant growth of rice and maize. Purwati, Soetopo, & Setiawan (2007) reported that the addition of fly ash of dose of 10 kg tree⁻¹ or 10 t ha⁻¹ per period of planting can enhance plant growth

significantly in peat soil, while Rejeki, Nelvia, & Saryono (2014) reported that the addition of dosage of 50-75 g pot⁻¹ increased weight of plant biomass.

The use of fly ash dose of 75 g pot⁻¹ increased yield of rice significantly but it did not significantly to age emerged panicles compared to without fly ash. The weight of 1000 grains and yield of rice increased by 15.69% and 102.95%, respectively compared to without fly ash. At a highest dose of fly ash (125 g pot⁻¹), the increase weight of 1000 grains tended to decrease (11.52%), the yield of rice relatively similar (102.55%) but the age of panicle emerge tends to be faster (Table 5). The use of fly ash increased the availability of essential nutrients were enough and balanced until the generative phase so that it increased physiology and metabolism process. Increasing of photosynthesis process would increase the amount of assimilate (carbohydrates). Carbohydrates was converted to be starches, protein and other organic compounds. The starch, protein and other organic compounds were components of grain. YosefTabar (2013) reported that the application of N and P fertilizer increased the number of grain, weight of 1000 grain and yield of rice. Another studies noted that application N fertilizer increased panicle per hill, total grains per panicle (Haque & Haque, 2016), weight of 1000 grains and yield of the grain (Haque & Haque, 2016; Mandana, Akif, Ebrahim, & Azin, 2014; YosefTabar, 2013). Arivazhagan et al. (2011) reported that the application of fly ash at 50 tha⁻¹ increased the yield of cereal crops from 5-20%, vegetable crop from 5-20%, plantation crops from 20-30%, rice crop 13-17%, sugarcane crop from 15-30%, maize crop from 36-40% and potato crop from 25-37% over control. The application of rice husk ash with fertilizer N, P and K can increase production, quality and quantity of grains (rice) (Suwanto, Sutrisno, & Suryono, 2015).

Yield of rice was positively correlated with the number of panicles, weight of 1000 grain and dry

straw weight (Table 6). This was closely related to the improvement of soil chemical properties such as increasing soil pH, macronutrient and micronutrient availability (Table 3). The use of higher fly ash doses (75 to 125 g pot⁻¹) increased soil pH and nutrient availability for plants higher than the dose of 25 g pot⁻¹. As a result, nutrients are increasingly absorbed by plants and further spur physiological and metabolic processes so that the formation and filling of grain is more perfect. The number of productive tillers, the weight of 1000 grains and the weight of dry straw were higher and the age emerged panicle was faster causing the higher yield of rice. The duration of the assimilation mobilization rate and the seed filling phase are the determinants of grain weight (Barnabás, Jäger, & Fehér, 2008). The faster the age emerged panicle can maximize the mobilization of assimilates so that there is an increase in weight of 1000 grains and yield of rice. The increase in the number of panicles, weight of 1000 grains and weight of dry straw caused the yield of rice to increase by giving of fly ash..

CONCLUSION AND SUGGESTION

The best plant growth and yield of rice were gained from the application of fly ash at the lower dose (25 g pot⁻¹ and 75 g pot⁻¹, respectively). The increase in fly ash dose (100 g pot⁻¹ and 125 g pot⁻¹) did not give the highest rice yield (9.67% and 0.2% lower than the dose of 75 g pot⁻¹) due to the macro nutrients N, P and K as a limiting factor (only as a basic fertilizer).

Based on the results of the study recommended to use fly ash dose of 75 g pot⁻¹ (15 t ha⁻¹) for rice cultivation on peat soil to get better growth and higher yields. However, further research is needed to obtain the optimum doses of N, P and K fertilizers and fly ash.

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