CARBON EMISSION AND RESPONS OF RICE TO APPLICATION OF AMELIORANT DREGS IN THE PEAT SOIL WITH SATURATION AND UNSATURATION

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Abstract. *Fertility of peat land is very poor and makes it not suitable for crop without any high input. This condition was indicated by the very high soil's acidity (low pH), low availability of macro (N, P, K, Ca and Mg), and micro (Cu, Zn, Mn and Bo) nutriens and high cation exchange capacity (CEC) but low base saturation (BS), the presence of toxic organic acid. The main organic acids, as a result of lignin biodegradation and the sources of C-release, are of aromatic group consisting mainly of derivate phenolic acids.*

This research was conducted in a greenhouse. The peat soil was taken at depths from 0 to 30 cm, with weathering rate saprik and dregs from dregs from pulp and paper industry at Kerinci,, Pelalawan, Riau. This research used split-plot design, activities were focused on the interaction of ameliorant dregs and water condition (saturation and unsaturation) and its influences to rice yield and C-emission (CO_2 and CH_4).

The application of dregs at the dose 20 t ha^{-1} decreased the CO_2 and CH_4 production of about 16.5% and 13.7% respectively at saturation and about 9.9% and 91.0 % respectively at unsaturation compared to without ameliorant. The application of dregs 10 to 20 t ha^{-1} increased plant height, maximum tiller number, number of productive tillers and weight of dry straw and milled dry grain of rice IR-64. The weight of dry straw and milled dry grain increased about 110 to 210% and 75 to 174% respectively at saturation and 59 to 92 to % and 52 to 80% respectively at unsaturation compare to without ameliorant.

Keywords*:* Ameliorant dregs, peat soil, water condition, CH_4 and CO_2 emission, rice

1. Introduction

Indonesia has 188 milion ha land, including peatland about 20.9 million ha, (Wahyunto et al., 2005). Peatland fertility is very poor and makes it not suitable for crop without any high input. This condition was indicated by the very high soil acidity (low pH), low availability of macro (N, P, K, Ca and Mg), and micro (Cu, Zn, Mn and Bo) nutriens and high cation exchange capacity (CEC) but low base saturation (BS), and the presence of toxic organic acid (Simbolon, 2009).

The main organic acid, as a result of lignin biodegradation and the sources of C-release, are of aromatic group consisting mainly of derivate phenolic acids. The concentration of such organic acids ranging from the highest to lowest is as follows: ferulic acid ≈ synapic acid > p-coumaric acid > p-hydroxybenzoic acid > vanilic acid > syringic acid (Sabiham, 2010). Phenolic acids are more phytotoxic for plants and causes stunted plant growth (Tsutuski, 1984; Stevens, *et al.*, 1994; Dohong and Sabiham, 2001), influence the biochemical and physiological processes of plants and nutrients uptake by plant (Driessen, 1978).

The drying and wetting processes on the peat materials affected the stability of organic acids, wich was indicated by loss of C- through CO_2 and CH_4 releases. The release of CO_2 and CH_4 from fibric peat was higher than that from hemic and sapric peats (Sabiham, 2010). Yagi and Minami (1990) reported that the highest rate of CH_4 emission during cultivation period (44.8 g CH_4 m^{-2}) was in

The drainage of peat release oxigen (O_2) into the surface, with promotes decomposition. Emission estimates, for land use systems with a depth of 60 cm drainage is around 55 Mg CO_2 ha^{-1} $year^{-1}$ (Hooijier *et al.* 2010), based on a linear relationship between depth of water table and emissions. Phenolic acids and C-release could be reduced to the granting of polivalen cations such as Al, Fe, Cu, Zn and Mn, thus reducing the bad effects. Where the stability of complexes between humic acid-metal getting weaker in the order of $Al^{3+} > Fe^{3+} > Cu^{2+} > Mn^{2+} > Zn^{2+} >> Mg^{2+} > Ca^{2+}$ (Tan, 2003).

Rini (2005) reported that dregs (dregs is a waste recausticizing process in the pulp industry) containing macronutrients N, P, K, Ca and Mg about 0.4, 0.7, 0.4, 3.2 and 0.48 g kg^{-1} and micronutrients Fe, Zn, Cu and Mo about 52.12, 20.14, 50.20 and 3.14 mg kg^{-1} respectively, and Nelvia *et al.* (2009) reported that the application of dregs 15 ton ha^{-1} increase dry weight shoot of maize at 40 days after planting about 126% compared without dregs.

This research aimed to study the potential of using dregs to reducing C-release (CO_4 and CH_4) and increasing growth and yield of rice on peat soil at saturation and unsaturation.

2. Material And Method

This research was conducted from July to October 2009 in a greenhouse of Agriculture Faculty of Riau University. Soil chemical properties of peat soils and dregs was analyzed at soil laboratory of Soil Research Bogor.

Preliminary analysis of chemical characteristics of peat soil before the experiment i.e.: pH (pH meter), BS, CEC (1 N NH_4OAc pH 7.0)(Black, 1965), organic C (Walkley and Black)(Black, 1965), total N (Kjeldahl)(Black, 1965), the ratio of C/N, P_2O_5 available (Bray-1)(Black, 1965), total P_2O_5 (HCl 25%)(Black, 1965), exchangeable bases (K, Ca, Mg and Na) (1 N NH_4OAc pH 7.0)(Black, 1965), available micronutrients (Fe, Cu, Zn and Mn) (DTPA)(Black, 1965), the total micronutrients (Fe, Cu, Zn and Mn) ($HClO_4$ + HNO_3 pa)(Page *et al.* 1982) and ash content (gravimetry)(Blackemore *et al.* 1987). Analysis of chemical characteristics of dregs included analiysis: pH (pH meter), total of macronutrients (P, K, Ca, Mg, Na and S) and micronutrients (Fe, Cu, Zn and Mn) ($HClO_4$ + HNO_3 pa)(Page *et al.* 1982), macro and micro nutrient available (2% citric acid)(Black, 1965) and moisture content (oven dried 105 °C) (Sudjadi *et al.* 1971).

The peat soil material was taken at depths from 0 to 30 cm, with weathering rate saprik at Kerumutan village, Pelalawan Regency, Riau Province, while dregs (dregs is a waste recausticizing process in the pulp industry) from Riau Andalan Pulp and Paper (RAPP) industry at Kerinci, Pelalawan, Riau. This research used split-plot experiments in completely randomized design, activities were focousd on the interaction of ameliorant dregs (0, 10, 15 and 20 tons ha^{-1} (0, 50, 75 and 100 g pot^{-1}) and water condition (saturation and unsaturation) and its influences to rice yield and C-emission (CO_2 and CH_4).

Implementation of research: peat soil material equivalent of 2 kg dry weight oven 105 °C and drges was mixed with appropriate treatment and then incubated at saturation and unsaturation condition for 1 month and then the IR-64 variety rice was planted. Basic fertilizers: Urea, TSP, and KCl each with a dose of 350, 150, and 150 kg ha^{-1} respectively. Whole TSP, KCl and 1/2 doses urea given one day before transplanting and 1/2 other urea given 30 days after planting. Dosages are calculated based on the weight of the soil, with the assumption that 1 ha of soil weight is 400 000 kg with BD 0.2 g cm^{-3} (Driessen, 1978).

To measure the flux of CO_2 and CH_4, a chamber for trapping the gases made from the fiberglass with the size of 0.75 m x 0,20 m x 0,20 m, was used Syringes were used to take the samples of gases from the chamber. The samples were then put on the vacuum bottles. In this research, Gas ...adzu C-R6A were used to determine the

CO_2 and CH_4 emissions. The emissions were calculated by using following equation (Boer *et al.*, 1996):

$$F_M = \{(d[CO_2/CH_4]dt \times h_U \times 16.123\ (44.01) \times 273.2 \times (60/22.410))/(t_U + 273.2)\ mg\ m^{-2}\ h^{-1}\}$$

Where: $d[CO_2/CH_4]dt$ = change of the concentrations of CO_2 and CH_4 in chamber after the periode of t minute (s); h_U = the height of chamber; t_U = the average of air temperature in chamber; Value of 16.123 = the weight of CH_4 molecule, 44.01 = weight of CO_2; Value of 273.2 = temperature in Kelvin; 22.41 = volume of gas molecule; and Value of 60 meants 60 minutes (1 hour). Other parameters were observed between: plant height, the maximum tillers and productive tillers number, straw dry weight and grain dry milled weight.

3. Results And Discussion

3.1 Characteristics peat and dregs

Several chemical characteristics of peats, interesting results to discuss. The C/N ratio of peats is still very high. Even though total N high, but C/N ratio is very high which means N is still the composer of peat organic matter structure, causing N availabilty to plants is very low, thereby becoming a limiting factor for plant growth. Cation exchange capacity value is very high, but BS is very low, thus inhibiting the provision of nutrients, mainly K, Ca and Mg for plants. The situation got worst because exchangeable Na, K, Ca and Mg is very low and therefore inhibit the growth and yield. Availability and total micro nutrient content are very low except for Fe is quite high, causing micro nutrient deficient for plants. According to Simbolon (2009) peat soil pH is very low, the availability of macro (N, P, K, Ca and Mg) nutrient are low and deficient micro (Cu, Zn, Mn, Fe, B and Mo) nutrient, CEC is very high but BS is low. Where the availability of Cu is the lowest compared to other micro nutrient because the Cu bounds to organic compounds functional groups such as carboxyl (COOH) and phenolic (-OH) to form organo—cation complex of Cu (chelate) that are not available for plants. Tim Kebijakan Sintesis (2008) reports that rice plants grown in peat soil with a thickness of over 2 m deficient Cu failed to form a grain.

Several chemical charateristics of dregs are macro and micro nutrient contained in drges quickly available in peat, the extraction with 2% citric acid is almost equal to the total content of macro and micro of nutrients (Table 2). Dissociation of H ions from organic compounds cause the concentration of H^+ ions on peat soil is very high, H^+ ions can hydrolyze dregs so that it dissolves quickly. Results of analysis of havy metal content in the drges (Table 3) showed that (Pb, Cd, As, Hg, Co, Ni, Cr, Ag, Sn and Mo) total are very low according to the standard value Kep.04/Bapeda/IX/1995 quality of group A and B (Table 4) are not including those identified B3 waste so it can be dumped in landfill ligh tweight category.

Table 1. Chemical characteritics and ash content of peat soils used in this research

Chemical characteristics	Value	Chemical characteristics and ash content	Value
pH H_2O (1:5)	3,2	Base Saturation (%)	6
pH KCl (1:5)	3,0	Micro nutrient (DTPA)	
Organic-C (%)	43,73	Fe (mg kg^{-1})	475
Total-N (%)	0,65	Mn (mg kg^{-1})	1
C/N ratio	67,28	Cu (mg kg^{-1})	2
Exc.Ca (cmol (+) kg^{-1})	2,27	Zn (mg kg^{-1})	2
Exc.Mg (cmol (+) kg^{-1})	0,68	Micro nutrient ($HNO_3 + HClO_4$ pa)	
Exc.K (cmol (+) kg^{-1})	0,22	Fe (mg kg^{-1})	3606
Exc.Na (cmol (+) kg^{-1})	0,26	Mn (mg kg^{-1})	12,3
P_2O_5 (mg kg^{-1}) (Bray I)	135,4	Cu (mg kg^{-1})	3,1
P_2O_5 (mg kg^{-1}) (HCl 25%)	320	Zn (mg kg^{-1})	4,8
CEC (cmol (+) kg^{-1})	72,45	Ash content (%)	15,89

Table 2. Chemical characterization and moisture of dregs

Chemical characterization and ash content	**value**	**Chemical characterization**	**value**
pH H_2O (1:5)	9,3	Macro nutrient (Citric Acid 2%)	
Macro nutrient ($HClO_4$ & HNO_3 pa)		P_2O_5 (g kg^{-1})	1,8
P_2O_5 (g kg^{-1})	2,0	K_2O (g kg^{-1})	3,1
K_2O (g kg^{-1})	3,1	CaO (g/kg)	409,7
CaO (g kg^{-1})	410,3	MgO (g kg^{-1})	23,2
MgO (g kg^{-1})	23,9	Na (g kg^{-1})	25,9
Na (g kg^{-1})	26,8	S (g kg^{-1})	6,4
S (g kg^{-1})	7,2	Micro nutrient (Citric Acid 2%)	
Micro nutrient ($HCLO_4$ & HNO_3 pa)		Fe (mg kg^{-1})	3244
Fe (mg kg^{-1})	5000	Mn (mg kg^{-1})	914
Mn (mg kg^{-1})	989	Cu (mg kg^{-1})	105
Cu (mg kg^{-1})	127	Zn (mg kg^{-1})	206
Zn (mg kg^{-1})	224	moisture (%)	15,8 9

Table 3. Heavy metal content of dregs

Chemical characteristic	value	Chemical characteristic	value
Extraction ($HClO_4$ + HNO_3 pa)		Extraction (citric acid 2%)	
Pb (mg kg^{-1})	8.9	Pb (mg kg^{-1})	0.1
Cd (mg kg^{-1})	0.2	Cd (mg kg^{-1})	nm
As (mg kg^{-1})	3.8	As (mg kg^{-1})	nm
Hg (mg kg^{-1})	0.23	Hg (mg kg^{-1})	nm
Co (mg kg^{-1})	1.7	Co (mg kg^{-1})	1.5
Ni (mg kg^{-1})	98.6	Ni (mg kg^{-1})	98.5
Cr (mg kg^{-1})	167	Cr (mg kg^{-1})	120
Se (mg kg^{-1})	355	Se (mg kg^{-1})	169
Ag (mg kg^{-1})	nm	Ag (mg kg^{-1})	nm
Sn (mg kg^{-1})	nm	Sn (mg kg^{-1})	nm
Mo (mg kg^{-1})	nm	Mo (mg kg^{-1})	nm

Note: nm = not measurable

Table 4. Standard value of total heavy metals by Kep 04/Bapedal IX/1995

Chemical characteristic	Standars value Kep.04/Bapeda IX/1995	
	A category	B category
Pd (mg kg^{-1})	3000	*300*
Cd (mg kg^{-1})	50	*5*
As (mg kg^{-1})	300	*30*
Hg (mg kg^{-1})	20	*2*
Cr (mg kg^{-1})	2500	*250*
Ni (mg kg^{-1})	1000	*100*
Se (mg kg^{-1})	100	*10*
Sn (mg kg^{-1})	500	*50*
Zn (mg kg^{-1})	5000	*500*
Co (mg kg^{-1})	500	*50*
Cu(mg kg^{-1})	1000	*100*
Mo (mg kg^{-1})	400	*40*

vironmental impact

3.2 The effect of application of ameliorant dregs in the peat soil at saturation and unsaturation condition on carbon emission

Carbon release in the forms of CO_2 and CH_4 fluxes, the use of dregs as ameliorant with a dose 10 to 20 t ha^{-1} was able to reduce CO_2 and CH_4 production from peat at 42 days after planting of rice IR-64 (Table 5). The application of dregs at the dose 20 t ha^{-1} decreased the CO_2 and CH_4 production of about 16.5% and 13.7% respectively at saturation and about 9.9% and 91.0 % respectively at unsaturation compared to without ameliorant . The main organic acids, as a result of lignin biodegradation and the sources of C-release in peat soil are, are of aromatic group consisting mainly of derivate phenolic acids. The decrease is caused by the formation of stable complex bonding between polivalen (Fe, Cu, Zn, Mn) cation and organic acids (phenolic acids) as can be shown by the illustraton of the reaction in Fig. 1.

Table 5. The effect of application of ameliorant dregs in the peat soil at saturation and unsaturation condition on the CO_2 and CH_4 production (mg pot^{-1} h^{-1})

Dregs (ton ha-1)	Saturation		Unsaturation	
	CO_2 production	CH_4 production	CO_2 production	CH_4 production
0	18722 ab	6693 abc	8115 ab	29702 a
10	29713 ab	7606 abc	6639 c	1867 c
15	52567 a	19385 a	8378 ab	3069 bc
20	15643 ab	5777 ab	7311 c	2678 bc

Note: The numbers in the same columns which followed the same lowercase letter are not significantly different at 5% DNMRT test

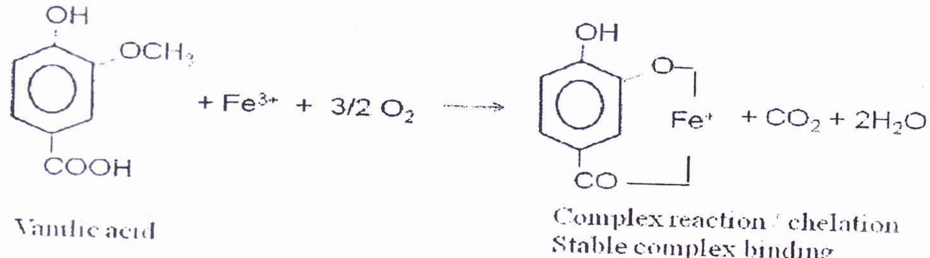


Fig. 1. An example of interaction between vanilic acid and Fe3+ in condition of low soil pH (Sabiham, 2010)

With such formation, peat would be more resistant to decomposision process, thereby reducing the production of CO_2 and CH_4. Where the stability of complexes between humic acid-metal getting weaker in the order of $Al^{3+} > Fe^{3+} > Cu^{2+} > Mn^{2+} > Zn^{2+} >> Mg^{2+} > Ca^{2+}$ (Tan, 2003). Sabiham (2010) reported that the use of Fe^{3+} as ameliorant was able to reduse CO_2 and CH_4 from peat soil, the use of at rate of 7.5% maximum sortion sharply decreased the CO2 and CH4 productions of about 42.1 to 30.6 to 34.8%, respectively, and reported that the using ameliorant of (50% mineral soil + 50% basic slage). the total C-loss decreased to about 1.49 t C ha^{-1} yr^{-1} (28%) in fresh water peat, 1.38 t C ha^{-1} yr^{-1} (30%) in brackish peat, and 1.34 t C ha^{-1} yr^{-1} (31%) in marine peat.

3.3 The effect of application of ameliorant dregs in the peat at saturation and unsaturation condition on growth and production of rice IR-64

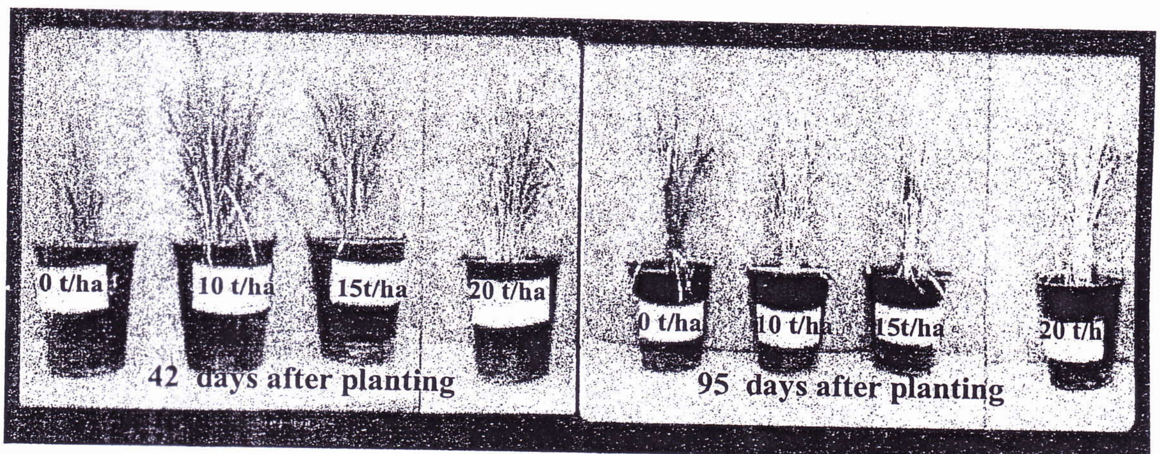
The addition of ameliorant also increased the growth and yield of rice, as can be seem in Table 6 and Fig. 2. Base on the observation results, however, rice did not seems to be able to grow well on without ameliorant. The peat composition is dominated by lignin of 65% to 80% and 78% to 93% for the peats of Jambi and Central Kalimantan repectively (Sabiham, 2010), and 71,46% for the peats of Riau (Nelvia, 2009). Orlov (1995) showed the processes of lignin disintegration that result in several derivate phenolic acids. Phenolic acids are more phytotoxic for plants and causes stunted plant growth (Tsutuki, 1984; Stevens, *et al.*, 1994; Dohong and Sabiham, 2001), influence the biochemical and physiological processes of plants and nutrients uptake by plant (Driessen, 1978).

Tsutsuki *et al* (1994) stated that the concentration of phenolic acids at the range of 0.6 to 3.0 mM could hamper the root growth of rice up to 50%. Todano *et al* (1992) reported that derivate phenolic acids, such as ferulic, synapic, p-cumaric, and p-hydroxybenzoic acids are phytotoxic for rice, particularly during the first stage of plant groth. He also mentioned that ferulic acid in peat is more toxic compered to the other derivate phenolic acids.

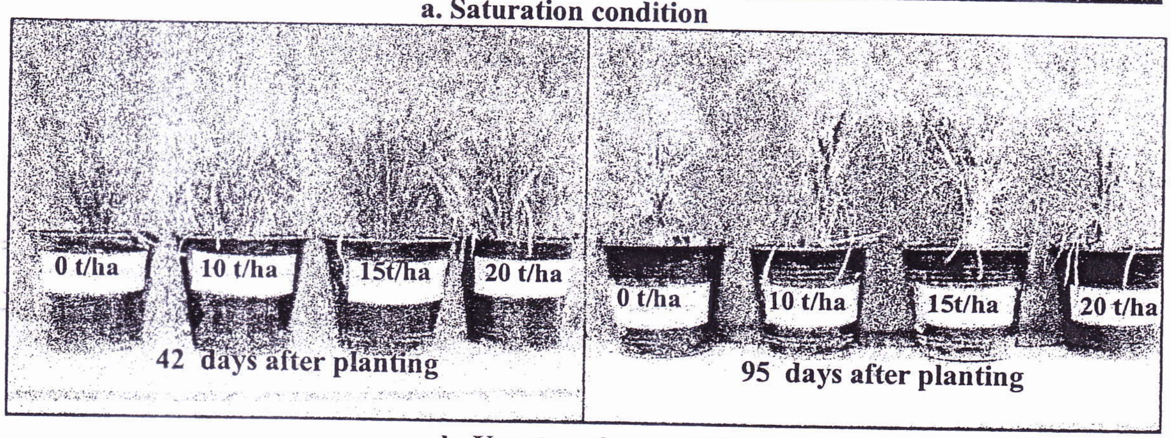
Table 6. The effect of ameliorant dregs in the peat on the plant height (cm), maximum and productive tillers (number plot^{-1}) and weight of dry straw and milled dry grain (g pot^{-1}) of rice IR-64

Dregs	Saturation					Unsaturation				
ton ha^{-1}	P H	MT	PT	DS	MDG	P H	MT	PT	DS	MDG
0	47 c	20 d	17 c	20 c	20.0 c	52 b	20 d	19 c	27 c	29.8 c
10	66 a	33 c	23 bc	42 b	35.4 a	64 a	36 abc	31 bc	43 b	53.7 b
15	67 a	45 ab	31 a	61 a	54.8 b	68	35 bc	28 ab	46 b	53.0 b
20	67 a	47 a	30 a	62 a	54.9 b	66	36 abc	28 ab	52 b	45.3 a

Note : PH = Plant height,, MT = maximum tillers number and PT = productive tillers number, DS = dry straw, MDG = milled dry grain. The numbers in the same columns which followed the same lowercase letter are not significantly different at 5% DNMRT test.



a. Saturation condition



b. Unsaturation condition

Fig. 3. The growth of rice IR-64 at vegetative and generative phase in saturated (a) and unsaturated (b) condition

Table 6 and Fig. 3 show increased the growth and yield of rice. The application of dregs at the dosage10 to 20 t ha^{-1} increased plant height, maximum tillers number and productive tillers number, weight of dry straw and milled dry grain of rice IR-64. The weight of dry straw and milled dry grain increased about 110 to 210% and 75 to 174% respectively at saturation and 59 to 92 to % and 52 to 80% respectively at unsaturation compare to without ameliorant. The increase is caused by the formation of stable complex binding between polivalen (Fe, Cu, Zn and Mn) cation and derivate phenolic acids. Sabiham (2010) reported that the concentration of derivate phenolic acids namely: ferulic, syanapic, p-cumaric, vanilic, syringic and p-hydroxybenzoic acids in peats decreased with the addition of mineral soil or basic slag, or the combination of both materials. The formation of stable complex binding between Fe^{3+} or with other polivalen cation and derivate phenolic acid as can be shown by the illustraton of the reaction in Fig. 1. The application of dregs can be able decreased derivate phenolic acid soluble and increase makro (P, K, Ca, Mg) and mikro (Fe, Cu, Zn, Mn and Mo) available. Its caused by the dregs contain macro (P, K, Ca, Mg, S) and micro (Fe, Cu, Zn, Mn, Mo) nutrients or polivalen cations .

4. Conclusion

The application of dregs at the dose 20 t ha^{-1} decreased the CO_2 and CH_4 production of about 16.5% and 13.7% respectively at saturation and about 9.9% and 91.0 % respectively at unsaturation compared to without ameliorant.

The application of dregs 10 to 20 t ha^{-1} increased plant height, maximum tiller number, number of productive tillers and weight of dry straw and milled dry grain of rice IR-64. The weight of dry straw and milled dry grain increased about 110 to 210% and 75 to 174% respectively at saturation and 59 to 92 to % and 52 to 80% respectively at unsaturation compare to without ameliorant.

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