Available online at:
http://journal.unila.ac.id/index.php/tropicalsoil
DOI: 10.5400/jts.2014.19.1.35

Use of Ameliorants to Increase Growth and Yield of Maize (*Zea mays* L.) in Peat Soils of West Kalimantan

Denah Suswati[1], Bambang Hendro Sunarminto[2], Dja'far Shiddieq[3] and Didik Indradewa[4]

[1]*Department of Soil Science, Faculty of Agriculture, Tanjungpura University – Pontianak*
Jl. Ahmad Yani, Pontianak, 78124 phone: (0561) 736033 Fax: (0561) 739630
e-mail: denasponti@gmail.com
[2,3]*Department of Soil Science, Faculty of Agriculture, Gadjah Mada University – Yogyakarta*
[4]*Department of Agronomy, Faculty of Agriculture, Gadjah Mada University – Yogyakarta*

Received 31 October 2013/ accepted 2 January 2014

ABSTRACT

Peatland in Indonesia has a potential for maize cultivation, but it has constraints that low of soil pH and of nutrient availability. Use of ameliorants from coastal sediment and salted fish waste was an alternative to improve peatlands productivity and maize yields. Objective of the study was to examine effects of coastal sediment and salted fish waste on growth and yield of maize at three kinds of soil of peatlands of Kubu Raya, West Kalimantan. This research was conducted in field using Inter-area analysis design. The first factor was combination of each ameliorants which consisted of 5 levels, namely: 1) treatment under farmer custom at the sites (control); 2) coastal sediment of 20 Mg ha^{-1} + 0.75 Mg of salted fish waste ha^{-1}; 3) coastal sediment of 40 Mg ha^{-1} + 1.5 Mg of salted fish waste ha^{-1}, 4) coastal sediment of 60 Mg ha^{-1} + 2.25 Mg of salted fish waste ha^{-1}. The second factor was soil types which consisted of three levels, namely: Typic Haplohemists, Typic Sulfisaprists and Typic Haplosaprists. Each treatment was repeated 5 times. The results showed that combination of 40 Mg ha^{-1} of coastal sediment and 1.5 Mg ha^{-1} of salted fish waste was the best combination for all soil type. It increased plant height (33% - 44%), shoot dry weight (74% - 75%), number of seeds per cob (31% -110%), weight of 100 seeds (58% -71%) and dry grain weight per plant (136% -160%) at each soil. The highest yield was found in soil of Typic Haplosaprists (219.54 g), followed by Typic Sulfisaprists (210.72 g) and Typic Haplohemists (208.82 g).

Keywords: Coastal sediment, maize, peat soils, salted fish waste

INTRODUCTION

Maize (*Zea mays* L.) is economically a unique crop worldwide and economically importance (Vasal 2012). In Indonesia, maize is the second most important cereal crop after rice (Swastika *et al*. 2004). Presently, maize is not only as a staple food, but also as a major component of feeds for animal industry (Pasuquin 2010; Reddy *et al*. 2013) and biofuel (Kocar and Civas 2013). The targeted maize production was 29.000.000 Mg in 2014. In order to achieve maize self sufficiency, the area of production has to be increased to about 4.999.000 ha and the productivity to be 5.82 Mg ha^{-1} (Haryono 2012). Maize production in Indonesia can be increased by both intensifying cultivation practices and expansion of cultivable area (Margaretha 2012).

With lesser availability of mineral land for agricultural expansion, role of peat land is increasingly important, especially in provinces which exist peatlands dominantly (Agus *et al*. 2010). Kubu Raya Districts of West Kalimantan has 408,369 ha (58%) peatlands of total land area of 698,520 ha (Wahyunto *et al*. 2010). Land use changes by conversion of tropical peatland for agriculture are becoming more significant (Veloo *et al*. 2014). That area still has 64% of the peatland areas covered by peat swamp forest, few industrial plantations (4%) and most of the managed areas are occupied by small-holder farmers (11%) (Hansen *et al*. 2009; Miettinen and Liew 2010). According to Anshari *et al*. (2010) the distribution of peats in this province greatly associates with rivers, lakes, and inundated depression region. Peat soils mostly have low to very low nutrient, acid and naturally accumulate under anaerobic conditions (Sabiham *et al*. 2012). In addition, peat soils have limitations with unavailability of potassium (K), sulphur (S), zinc (Zn), and copper (Cu) (Masud *et al*. 2011; Abat *et al*. 2012). A low nutrient might limit decay because lack of available cations that were so strongly bound to negative exchange sites within peat (Gogo and Pearce 2009).

Addition of ameliorants would increase peat soil fertility and productivity (Sabiham 2010; Nurzakiah *et al*. 2013) and reduced rate of peat decomposition (Husen and Agus 2011). The alternatives amelioration applied to maize farms in Kubu Raya peatlands was coastal sediment and salted fish waste which was easily obtained, relatively available and relatively cheap price (Heny and Suswati 2010). Sabiham (1996) explained that addition of coastal sediment to peat soil might raise soil pH, due to neutralized- reaction of ion H^+ from peat by ions OH^- of base cations contained at coastal sediments. An increase in soil pH would increase activity of soil microorganisms which were actively at soil pH 6 - 7 in peat soil (Blonska 2010; Sullivan *et al*. 2013).

Fishing produced large quantities of waste daily in fish markets and fish processing industries (Laos *et al*. 1998). These large quantities of fish waste have not been utilized efficiently, and disposal of fish waste might produce large negative impacts on local environments (Kim 2011). Fish waste has also been traditionally used as fertilizer, given their wealth of nutritive nutrient (principally N and P) and their rapid decomposition (Mosquera *et al*. 2011). Composting initiatived using fish offal derived mainly from aquiculture have been carried out in various parts of the world as alternative and viable techniques for transforming fish waste into useful agricultural products (Kinnunen *et al*. 2005).

The purpose of this study was to determine effect of application of coastal sediment and salted fish waste as ameliorant on growth and yield of maize (*Zea mays* L.) in peatlands of Kubu Raya Districts of West Kalimantan.

MATERIALS AND METHODS

Study Site and Materials

The research was conducted in the field of Rasau Jaya III area, Kubu Raya Regency, for 4 months starting from March - June 2012. Based on characteristics of the land, there were three kinds of soil map unit (SMU) *i.e*.: SMU 1 (Typic Haplohemists), SMU 3 (Typic Sulfisaprists) and SMU 4 (Typic Haplosaprists) (Suswati *et al*. 2011).

Coastal sediments used in this experiment were obtained from Kijing beach and salted fish waste from local market. Fertilizer requirement of N, P, K for maize were applied based on calculation of soil analysis results and recommendations of N, P, and K maize plants. The Pioner 21 hybrid variety of maize seed was used in this experiment.

Experimental Treatments and Design

This research was conducted in field using Inter- area analysis design (Gomez and Gomez 2007). The first factor consisted of 5 levels, namely: 1) treatment under farmer custom at the sites; 2) coastal sediment of 20 Mg ha^{-1} + 0.75 Mg of salted fish waste ha^{-1}; 3) coastal sediment of 40 Mg ha^{-1} + 1.5 Mg of salted fish waste ha^{-1}, 4) coastal sediment of 60 Mg ha^{-1} + 2.25 Mg of salted fish waste ha^{-1}. The second factor consisted of three kinds of soils, *i.e*.: Typic Haplohemists (SMU 1), Typic Sulfisaprists (SMU 3) and Typic Haplosaprists (SMU 4). Each treatment was repeated 5 times.

The study used 20 experimental plots (each plot sized of 6 m × 3.8 m) for every soil. Maize was planted with a spacing of 75 cm × 20 cm, so there were 152 plants per plot. Each plot was taken 6 plants and randomly sampled to measure plant hight and dry weight at outside of swath, while 44 plants (swath size of 3 m × 2.2 m) were used for observation of number of seeds, weight 100 seeds, dry grain weight per plant and yield. Measurements of plant height, plant dry weight were carried out at maximum vegetative phase *i.e*. 54 days after planting. Soil samples for selected soil chemical and physical properties were taken at depths of 0-5 cm, 5-10 cm and 10-20 cm prior to maize planting time at every soil. Initial results of soil and ameliorant analysis are shown at Table 1.

Data Analysis

Statistical analysis of the data was run using Statistical Analysis System package (SAS Institute 2003). The Average separations among treatments were obtained by honest significant difference (HSD 0.05).

RESULTS AND DISCUSSION

Soil and Ameliorant Properties

Based on criteria for determining soil chemical properties (Hazelton and Murphy 2007), these three peat soil had a very acidic soil pH (3.26-3.76), high total N content, organic-C and C/N ratio. Since N is a structural constituent of peat organic matter so that it is not available for plant growth. Cation exchange capacity (CEC) value was very high but bases saturity (BS) was very low. It was likely to inhibit equilibrium of nutrients, especially K, Ca and Mg. Content of K, Ca and Mg nutrients were low, so that plant was deficiency of macro nutrient. According to Simbolon (2009) peat soil fertility was low, characterized by highly acidic soil pH, and low availability of N, P, K, Ca and Mg.

The results coastal sediment analysis (Table 1) indicated that the ameliorant had high base saturation but low CEC (15.33 cmol(+)kg^{-1}). The addition of coastal sediment on peat soil might raise soil pH due to neutralization reaction of H^+ ions from peat soil by OH^- ions from coastal sediment. Increasing soil pH will increase activity of soil microorganisms, which are actived at soil pH range 6-7 or around neutral. Due to increased activity of microorganisms in the soil, it would lower ratio of C/N in peat soil, so that N would be available to plants. Coastal sediment also contained high alkaline cations, which decreased CEC, increased BS and availability of cations Ca^{2+}, Mg^{2+}, Na^+, K^+. According to Salampak (1999), addition of cations through mineral soil material might decline carboxylic and phenolic acids content and CEC in peat soil. Moreover augmentation with these high valence cations might form a ligand complex with organic acids, and therefore improved soil fertility (Husen *et al*. 2013).

Table 1 shows that salted fish waste had a neutral pH, high organic-C and contained nutrients N, P, K^+, Ca^{2+}, Mg^{2+} and Na^+. In addition, application of salted fish waste on peat soil might diminish soil acidity and CEC, as well as enhance BS and availability of cations Ca^{2+}, Mg^{2+}, Na^+, K^+ (Suswati 2006).

Effect Application of Coastal Sediment and Salted Fish Waste on Maize Growth

Effect use of coastal sediment and salted fish waste on plant height of maize grown at each soil is presented at Table 2. It shows that the use of ameliorants significantly increased plant height while soil factor did not have significant effect on the variable as well as there was no interaction between the factors.

Table 2 shows that treatment of 20 Mg ha^{-1} of coastal sediment + 0.75 Mg ha^{-1} of salted fish waste increased plant height at maximum vegetative phase compared to untreated ameliorants. Treatment of 40 Mg ha^{-1} of coastal sediment + 1.5 Mg ha^{-1} of salted fish waste still significantly increased plant height, but was not different with application of 60 Mg ha^{-1} of coastal sediment + 2.25 Mg ha^{-1} of salted fish waste.

Analysis of variance results on shoot dry weight at maximum vegetative phase showed that application of ameliorant and soils significantly affected shoot dry weight, but there was no interaction between the factors. Table 3 shows that application of coastal sediment and salted fish waste at each soils increased shoot dry weight at vegetative phase maximum. In all soils, application 60 of Mg ha^{-1} coastal sediment + 2.25 Mg ha^{-1} salted fish waste increased shoot dry weight of maize. Aligned with the research of Hudson (2008), maize plants

Table 1. Initial soil analysis, coastal sediment and salted fish waste properties.

Soil properties	Soil			Coastal sediment	Salted fish waste
	Typic Haplohemists	Typic Sulfisaprists	Typic Haplosaprists		
Teksture					
Sand (%)	-	-	-	10.20	-
Silt (%)	-	-	-	51.85	-
Clay (%)	-	-	-	37.95	-
pH	3.26	3.76	3.62	8.13	6.08
Organic matter					
C-organik (%)	43.85	38.51	29.74	1.96	41.95
N-total (%)	0.71	0.67	0.64	7.26	7.66
C/N	61.76	57.48	46.47	0.27	5.48
Available P (mg P_2O_5 kg^{-1})	7.70	19.98	3.74	3.45	1.26 (%)
Potential K (mg K_2O kg^{-1})	1.07	1.23	0.84	1.71	0.59 (%)
Cation					
Exch. Ca (cmol(+)kg^{-1})	2.01	2.68	1.61	14.62	0.82(%)
Exch. Mg (cmol(+)kg^{-1})	1.49	1.79	1.30	1.73	0.30(%)
Exch. Na (cmol(+)kg^{-1})	2.66	3.12	2.17	2.65	0.29(%)
CEC (cmol(+)kg^{-1})	88.57	78.29	57.37	15.33	-
Base Saturated (%)	8.17	11.26	10.32	135.17	-
Exch. Al (cmol(+)kg^{-1})	16.42	0.66	18.67	-	-
Ash content (%)	7.91	11.09	16.13	-	-

grown in the soil amended with fish compost were germinated earlier, grew fastest and more healthier than plants without compost treatments.

Treatment of 20 Mg ha^{-1} of coastal sediment + 0.75 Mg ha^{-1} of salted fish waste increased shoot dry weight of maize at each soils. Treatment of 40 Mg ha^{-1} of coastal sediment + 1.5 Mg ha^{-1} of salted fish waste still significantly increased shoot dry weight of maize. Application of 60 Mg ha^{-1} of coastal sediment + 2.25 Mg ha^{-1} of salted fish waste also still significantly increased shoot dry weight of maize at Typic Sulfisaprists and Typic Haplosaprists, except at Typic Haplohemists.

Effect of Application of Coastal Sediment and Salted Fish Waste on Plant Yield

Analysis of plant components was perform after harvest (100 days after transplanting, DAT), which included number of seeds per cob, weight of 100 seeds and dry weight per plant, as shown in Table 4. The result of Analysis of variance indicated that application of ameliorant and soils as well as their interaction were significantly affected number of seeds per cob. Table 4 shows that coastal sediment and salted fish waste at each soil increased number of seeds per cob. In all soils, 60 Mg ha^{-1} of coastal sediment + 2.25 Mg ha^{-1} of salted fish waste affected number of seeds per cob.

Treatment of 20 Mg ha^{-1} of coastal sediment + 0.75 Mg ha^{-1} of salted fish waste enhanced number of grains per cob at every soil. Application of 40 Mg ha^{-1} of coastal sediment + 1.5 Mg ha^{-1} of salted fish waste significantly increased number of seeds per cob at Typic Haplosaprists, but was not significantly different at Typic Haplohemists and Typic Sulfisaprists. Effect of 60 Mg ha^{-1} of coastal sediment + 2.25 Mg ha^{-1} of salted fish waste on seed number per cob was likely to decrease, although there was no significant different with application of 40 Mg ha^{-1} of coastal sediment + 1.5 Mg ha^{-1} of salted fish waste at each soil. The results of Analysis of variance showed that application of ameliorants significantly affected weight of 100 seeds, but soil factor did not.

Table 2. Effect of coastal sediment and salted fish waste on plant height of maize grown in peat soils at maximum vegetative phase (54 DAP).

Combination of Ameliorants (Mg ha^{-1})	Soil			Average
	Typic Haplohemists	Typic Sulfisaprists	Typic Haplosaprists	
	Plant height (cm)			
0 (control)	155.42	142.23	162.21	153.29 c
20 + 0.75	242.59	228.2	232.33	234.37 b
40 + 1.50	248.87	252.7	241.18	247.58 a
60 + 2.25	243.57	242.13	234.58	240.09 ab
Average	222.61	216.31	217.57	(-)

Description: (-) no interaction, values followed by same letter in column and same treatment groups did not differ by Duncan's test 5%.

Table 3. Effect of coastal sediment and salted fish waste on shoot dry weight of maize grown in peat soils at maximum vegetative phase.

Combination of Ameliorants (Mg ha^{-1})	Soil			Average
	Typic Haplohemists	Typic Sulfisaprists	Typic Haplosaprists	
	Shoot dry weight (cm)			
0 (control)	41.21 e	43.25 e	55.11 e	46.52
20 + 0.75	128.36 d	111.18 d	121.86 d	120.47
40 + 1.50	157.96 bc	169.49 b	216.71 a	181.39
60 + 2.25	134.35 cd	123.88 d	118.01 d	125.41
Average	115.47	111.95	127.92	(+)

Description: (-) no interaction, values followed by same letter in column and same treatment groups did not differ by Duncan's test 5%.

Table 4 shows that use of 20 Mg ha^{-1} of coastal sediment + 0.75 Mg ha^{-1} of salted fish waste increased the weight of 100 seed. Treatment of 40 Mg ha^{-1} of coastal sediment + 1.5 Mg ha^{-1} of salted fish waste significantly increased weight of 100 seeds. Furthermore, application of 60 Mg ha^{-1} of coastal sediment + 2.25 Mg ha^{-1} of salted fish waste significantly reduced weight of 100 seeds and was not different by treatment of 20 Mg ha^{-1} of coastal sediment + 0.75 Mg ha^{-1} of salted fish waste. The results of analysis of variance showed that application of ameliorants significantly influenced dry grain weight per plant, but there was no significant effect between soil as well as no significant interaction between the factors. Application of ameliorants had significant effect on dry grain weight caused by two kinds of ameliorant used to have a high nutrient content to supply nutrients for the growth and yield of maize. Table 1 shows that coastal sediment contained high nutrient (N 7.26%, P 3.45 mg kg^{-1} and K 1.71 mg kg^{-1}), while salted fish waste contained N, P and K respectively 7.66%, 1.26% and 0.59%. Effect of soil factors and their interaction did not significantly different because the three peat soils were very acidic with soil pH ranged of 3.26-3.76. According to Diana *et al*. (2007) these characteristics reduce the availability of nutrients especially K, Ca, and Mg that are bound in such way that it is difficult for them to be utilized by plants. Painter (1991) suggested that cations are so strongly bound to negative exchange sites within peat. Eventually the plant will lack the nutrients during the growth and the yield is not optimal.

Table 4 shows that treatment of 20 Mg ha^{-1} of coastal sediment + 0.75 Mg ha^{-1} of salted fish waste increased weight of dry grain per plant. Application of 40 Mg ha^{-1} of coastal sediment + 1.5 Mg ha^{-1} of salted fish waste significantly increased dry grain weight per plant. However application of 60 Mg ha^{-1} of coastal sediment + 2.25 Mg ha^{-1} of salted fish waste significantly decreased dry grain weight per plant but the effect was no different with the application of 20 Mg ha^{-1} of coastal sediment + 0.75 Mg ha^{-1} of salted fish waste.

Application of ameliorant (coastal sediment + salted fish waste) increased soil pH because these ameliorants might contain high alkali cations (Suswati 2009). Furthermore, increasing soil pH enhanced availability of macro nutrients (N, P, K, Ca, Mg, and S). High nutrients in peat soil played a role in increasing plant height, dry weight, number of seeds per cob, weight of 100 seeds and dry grain weight per plant.

Table 4. Effect of ameliorants on yield components of maize in peat soils.

Combination of Ameliorants (Mg ha^{-1})	Soil			Average
	Typic Haplohemists	Typic Sulfisaprists	Typic Haplosaprists	
	Seeds per cob			
0 (Control)	337.17 e	434.87 d	272.53 f	348.19
20 + 0.75	506.20 c	532.20 bc	509.07 c	515.82
40 + 1.50	540.90 abc	570.10 ab	584.97 a	565.32
60 + 2.25	524.53 bc	530.60 bc	543.53 abc	532.89
Average	477.2	516.94	477.52	(+)
	Weight of 100 seeds (g)			
0 (Control)	19.61	18.67	20.12	19.47 c
20 + 0.75	26.07	24.15	25.42	25.21 b
40 + 1.50	32.88	31.97	31.86	32.24 a
60 + 2.25	25.4	25.65	24.37	25.14 b
Average	25.99	25.11	25.44	(-)
	Dry grain weight (g)			
0 (Control)	82.59	89.21	84.54	85.45 c
20 + 0.75	152.67	149.58	161.87	154.70 b
40 + 1.50	208.82	210.72	219.54	213.02 a
60 + 2.25	166.79	160.94	160.81	162.85 b
Average	152.72	152.61	156.69	(-)

Description: (-) no interaction, values followed by same letter in column and same treatment groups did not differ by Duncan's test 5%.

CONCLUSIONS

In conclusion, application of 40 Mg ha^{-1} of coastal sediment and 1.5 Mg ha^{-1} of salted fish waste was the best combination in increasing plant height, shoot dry weight, number of seeds per cob, weight of 100 seeds and dry grain weight per plant at each soil. The highest yield was found at Typic Haplosaprists, followed by Typic Sulfisaprists and Typic Haplohemists.

REFERENCES

Abat M, MJ McLaughlin, JK Kirby and SP Stacey. 2012. Adsorption and desorption of copper and zinc in tropical peat soils of Sarawak, Malaysia. *Geoderma* 176: 58-63.

Agus F, Wahyunto, Ai Dariah, P Setyanto, IGM Subiksa, E Runtunuwu, E Susanti and W Supriatna. 2010. Proc.of Int. Workshop on evaluation and sustainable management of soil carbon sequestration in Asian countries. Bogor, Indonesia Sept. 28-29, 2010: 217-233.

Anshari GZ, M Afifudin, M Nuriman, E Gusmayanti, L Arianie, R Susana, RW Nusantara, J Sugardjito and A Rafiastanto. 2010. Drainage and land use impacts on changes in selected peat properties and peat degradation in West Kalimantan Province, Indonesia. *Biogeosciences* 7: 3403-3419.

Blonska E. 2010. Enzyme activity in forest peat soils. *Folia Forestalia Polonica*, series A, 52: 20-25.

Diana N, S Parmiyatni, H Purwanta, G Angkoso and Koesnandar. 2007. Increase in pH of peat soil by microbial treatment. In: JO Rieley, CJ Banks and B Radjagukguk (eds). Proceedings of The International Symposium and Workshop on Tropical Peatland, Yogyakarta, 27-29 August 2007, EU CARBOPEAT and RESTORPEAT Partnership, Gadjah Mada University, Indonesia and University of Leicester, United Kindom.

Gogo S and DME Pearce. 2009. Carbon, cation dan CEC: Interactions and effects on microbial activity in peat. *Geoderma* 153: 76-86.

Gomez KA and AA Gomez. 2007. Statistical procedures for agricultural research. Second edition, an International Rice Research Institute Book. A Wiley Interscience Publication. P. 1-15: 97-116: 121-156.

Hansen MC, SV Stehman, PV Potapov, B Arunarwati, F Stolle and K Pittmann. 2009. Quantifying changes in rates of forest clearing in Indonesia from 1990 to 2005 using remotely sensed data sets. Environ Res Lett 4: 1-12. doi:10.1088/1748-9326/4/3/034001

Haryono. 2012. Maize for food, feed and fuel in indonesia: challenges and opportunity. In: Sumarno, M. Machmud and M Syam (eds). International Maize Conference: Agribusiness of Maize-livestock Integration at 22-24 November 2012 in Gorontalo; pp 3-9.

Hazelton PA and B Murphy. 2007. Interpreting soil test results: what do all the numbers Average? [2nd ed.]. CSIRO Publishing. Collingwood VIC 3066 Australia.

Heny S dan D Suswati. 2010. Pengaruh lumpur laut terhadap ketersediaan kation-kation basa pada tanah gambut untuk budidaya tanaman melon (*Cucumis melo* L.) *J Penelitian Universitas Tanjungpura*. 18: 15-25 (in Indonesian).

Hudson M. 2008. Mercury and Composting Fish Waste – A Pilot Project. Project Report 08-01. Great Lakes Indian Fish & Wildlife Commission: 22.

Husen E and F Agus. 2011. Microbial activities as affected by peat dryness and ameliorant. *Am J Environ Sci* 7: 348-353.

Husen E, S Salma and F Agus. 2013. Peat emission control by groundwater management and soil amendments: evidence from laboratory experiments. *Mitig Adapt Strateg Glob Change* 1381: 1-9. http://dx.doi.org/10.1007/s11027-013-9526-3

Kim JK. 2011. Cost-effectiveness of converting fish waste into liquid fertilizer. *Fish Aquat Sci* 14: 230-233.

Kinnunen RE, MC Gould and P Cambier. 2005. Composting commercial fish processing waste from fish caught in the Michigan Waters of the Great Lakes, Michigan State University Extension, USA.

Koçar G and N Civaº. 2013. An overview of biofuels from energy crops: Current status and future prospects. *Renew Sustain Energy Rev* 28: 900-916.

Laos F, MJ Mazzarinol, I Walter and L Roselli. 1998. Composting of fish waste with wood by-products and testing compost quality as a soil amendment: Experiences in the Patagonia Region of Argentina. *Compost Sci Util* 6: 59-66.

Margaretha SL, M Azrai and M Aqil. 2012. The Impact of cropping intensity on maize marketing in rainfed area. In: Sumarno, M Machmud and M Syam (eds). International Maize Conference: Agribusiness of Maize-livestock Integration at 22-24 November 2012 in Gorontalo, pp 242 -246.

Masud MM, M Moniruzzaman and MM Rashid. 2011. Management and conservation of organic peat soils for sustainable crop production in Bangladesh. *Bull Inst Trop Agr, Kyushu Univ*. 34: 93-101.

Miettinen J and SC Liew. 2010. Status of peatland degradation and development in Sumatra and Kalimantan. *Ambio* 39: 394-401.

Mosquera MEL, EF Lema, R Villares, R Corral, B Alonso, and C Blanco. 2011. Composting fish waste and seaweed toproduce a fertilizer for use in organic agriculture. *Proc Environ Sci* 9: 113-117.

Nurzakiah S, F Agus and H Syahbuddin. 2013. Ameliorant application on variation of carbon stock and ash content on Peatland South Kalimantan. *J Trop Soils* 18: 11-16. DOI: 10.5400/jts.2013.18.1.

Pasuquin JM, C Witt and M Pampolino. 2010. A new site-specific nutrient management approach for maize in the favorable tropical environments of Southeast Asia. 19th World Congress of Soil Science, Soil Solutions fora Changing World 1 – 6 August 2010, Brisbane, Australia.

Painter TJ. 1991. Lindow man, Tollund man and other peat-bog bodies: the preservative and antimicrobial action of sphagnan, a reactive glycuronoglycan with tanning and sequestering properties. *Carbohydrate Polym* 15: 123-142.

Reddy YR, D Ravi, CHR Reddy, KVSV Prasad, PH Zaidi, MT Vinayan and M Blummel. 2013. A note on the correlations between maize grain and maize stover quantitative and qualitative traits and the implications for whole maize plant optimization. *Field Crops Res* 153: 63-69.

Sabiham S. 1996. Pemanfaatan lumpur daerah rawa pasang surut sebagai salah satu alternatif di dalam menurunkan gas metana dan asam fenol pada tanah gambut tebal. Prosiding Seminar Nasional Gambut II, BPPT dan HGI, Jakarta (in Indonesian).

Sabiham S. 2010. Properties of indonesian peat in relation to the chemistry of carbon emission. proc.of int. workshop on evaluation and sustainable management of soil carbon sequestration in asian countries. Bogor, Indonesia Sept. 28-29, 2010.

Sabiham S, SD Tarigan, Hariyadi, I Las, F. Agus, Sukarman, P Setyanto and Wahyunto. 2012. A case study in oil palm plantations in west and central kalimantan, Indonesia. *Pedologist* 55: 426-434.

SAS [Statistical Analysis System] Institute. 2003. The SAS system for windows. Release 9.1. SAS Inst Inc, Cary, NC.

Salampak. 1999. Peningkatan produktivitas tanah gambut yang disawahkan dengan pemberian bahan amelioran tanah mineral berkadar besi tinggi. [Disertasi]. Institut Pertanian Bogor (in Indonesian).

Simbolon H. 2009. Local distribution and coexistence of prevalent tree species in peat swamp forests of central Kalimantan. *Reinwardtia* 12: 373-382.

Sullivan TS, MB McBride and JE Thies. 2013. Soil bacterial and archaeal community composition reûects high spatial heterogeneity of pH, bioavailable Zn, and Cu in a metalliferous peat soil. *Soil Biol Biochem* 66: 102-109.

Suswati D. 2006. Pengaruh kombinasi abu sawmill dan limbah ikan asin terhadap serapan p dan pertumbuhan tanaman lidah buaya (*Aloe vera*) pada gambut pontianak. *J Agripura* 2: 258-266 (in Indonesian).

Suswati D. 2009. Pengaruh lumpur laut terhadap beberapa sifat kimia tanah gambut. *J Agripura* 5: 757-765 (in Indonesian).

Suswati D, BH Sunarminto, D Shiddieq dan D Indradewa. 2011. Karakteristik dan kesesuaian lahan gambut untuk pengembangan jagung di Rasau Jaya III Kabupaten Kubu Raya. *J Agripura* 7: 984-990 (in Indonesian).

Swastika DKS, F Kasim, K Suhariyanto, W Sudana, R Hendayana, RV Gerpacio and PL Pingali. 2004. Maize in Indonesia: Production Systems, Constraints, and Research Priorities. Mexico, D.F.: CIMMYT. 50 p.

Vasal SK. 2012. Nutritionally enhanced maize and its importance in the developing countries. In: Sumarno, M. Machmud and M Syam (eds). International Maize Conference: Agribusiness of Maize-livestock Integration at 22-24 November 2012 in Gorontalo, pp 39-45.

Veloo R, S Paramananthan and E Van Ranst. 2014. Classification of tropical lowland peats revisited: The case of Sarawak. *Catena* 118: 179-185.

Wahyunto, W Supriatna and F Agus. 2010. Land use change and recommendation for sustainable development of peat land for agriculture: Case study at Kubu Raya and Pontianak Districts, West Kalimantan. *Indo Agric Sci* 11: 32-40.