Effect of zeolite, volcanic sand and sea water on bulk density of peat soil and growth of rice

Sarifuddin
Faculty of Agriculture, Universitas Sumatera Utara, Medan, Indonesia

E-mail: sarifuddin@usu.ac.id

Abstract. In addition to the problem of low nutrient availability, bulk density is also an important limiting factor on peat soil. The aims of this research was to determine the effect of zeolite minerals and volcanic sand after leached by sea water as ameliorants on changes the bulk density of peat soils to improve the fertility of peat soil and its effects on the rice that conducted in the greenhouse. The experimental design used was factorial randomized block design consist of 2 factors, factor 1 was the type of mineral with 3 treatments and factor 2 was sea water dosage with 4 treatments. Result showed that the volcanic sand was the most effective ameliorant in increasing soil bulk density and rice growth. Application of 1000 g volcanic sand and mixture of 200 g zeolite + 1000 g volcanic sand and then leached by 500 ml seawater per pot each other gave the best results for growing rice plants, namely number of vegetative tillers, generative tillers, dry weight of shoot and roots in peat soil, in contrast, leached with 1500 ml sea water was reduced the rice growth.

1. Introduction.
Peat soil problem mainly is the low nutrient availability for plant and also has physical limitation such as low bulk density (BD) caused by the low amount of minerals contained in the peat soil material. The low of bulk density to causing weak root support of plant roots so that it easily collapses, also affects unbalanced macro and micro pore size distributions. Pore size distribution affects nutrient and water storage and supply. Compaction can also improve the distribution of pore size even though fibric and hemic peat soil results are not as good as sapric peat soil which is not compacted.

Several studies have been conducted to improve the fertility of peat soil, among others by mixing peat with mineral soil, liming and giving iron to soybean plants [1], giving Na salts and some micro elements to rice yields [2], application of the high iron mineral soil [3], high iron mineral soil enriched with high iron matter [4], lime [5], steel slag combined with single and compound fertilizer on rice[6] and the provision of fly ash in acasia plants [7] and the mixing of pyrite mineral soils combined with washing on rice[8].

The provision of volcanic sand on peat soil has not been widely carried out but is expected to increase bulk density, mineral content and nutrient reserves that can affect over a longer time to improve the physical-chemical properties of peat soils. Volcanic sand derived from parent material of andisol contains around 43.06 - 67.96% SiO₂ and 12.55 - 29.92% Al₂O₃, 6.82 - 11.29% Fe₂O₃ and CaO, K₂O, MgO, Na₂O, P₂O₅ and TiO is less than 5% [9]. Zeolites are hydrated porous crystalline aluminosilicates containing pores in the form of interconnected hollow structures with sizes of 3 to 10 Å. Zeolites are composed of silicon, oxygen, and aluminum in a three-dimensional structure with pores containing...
water molecules and can adsorb cation exchangers. Based on the chemical composition, zeolite has an empirical formula: M_{2n} \cdot Al_{2}O_{3} \cdot x SiO_{2} \cdot y H_{2}O, where M is alkali or alkaline earth, n is valence, x is 1 - 10 and y is number 2 - 7. The most common empirical formula of clinoptilolite as natural zeolite is (Na, K) \cdot 2 O \cdot Al_{2}O_{3} \cdot 10 SiO_{2} \cdot 6 H_{2}O or [Na_{4}K_{4}][Al_{8}Si_{40}]O_{96} \cdot 24 H_{2}O [10]. Zeolites minerals through their properties as ion exchangers can adsorb certain salt ions which are present in excessive amounts in added sea water that has high content of essential dissolved elements such as 1,727 ppm Mg, 884 ppm S, 400 ppm Ca, 380 ppm K, although the Na and Cl content is also quite high at 10,561 ppm Na and 18,980 ppm Cl [11]. Therefore, seawater is potential as an alternative to ameliorant for nutrient poor soils such as peat soil. This study aims to look at changes of bulk density of peat soil after being given zeolite, volcanic sand and sea water then leachates with free ion water and its effect on rice plants.

2. Material and Method

The research was carried out at the greenhouse, Laboratory of Soil-Fertility and Research and Technology Laboratory of the Faculty of Agriculture, Universitas Sumatera Utara Medan. Peat soil from Rawasari Village (02°42'33.9" LU and 99°46'34.3" BT) Aek Kuasan District, Asahan Regency. Zeolite from PT. Dunia Windu Medan and volcanic sand taken from the bottom soil layer (C horizon) at the foot of Mount Sinabung Karo Regency. Urea, SP36 and MOP, as basic fertilizers, rice variety are Dendang from the Sukamandi Rice Research Institute, West Java, Indonesia.

The study used factorial randomized block design consisting of 2 treatments, consist of mineral types and sea water dosage with 3 replications, namely, M0 = without zeolite and volcanic sand, M1 = 200 g zeolite, M2 = 1000 g volcanic sand, M3 = mixture of 200 g zeolite and 1000 g volcanic sand. A0 = 0 ml of sea water (2000 ml of fresh water), A25 = 500 ml of sea water (+ 1500 ml of fresh water), A50 = 1000 ml of sea water (+ 1000 ml of fresh water), A75 = 1500 ml of sea water (+ 500 ml of fresh water) per pot equivalent with 10 kg of wet peat. Further analysis to test the difference in mean using the Duncan Multiple Range Test α = 5% [12,13]. A total of 10 kg of wet peat soil is given 200 g or 2% Zeolite and 1000 g or 10% of volcanic sand of the weight and then incubated for 2 weeks. Furthermore, each treatment was leached with seawater according to the prescribed treatment. The leaching water of each treatment was collected and returned back to each pot repeatedly until the leached water was discharged and incubated for 2 weeks. Before planting, leaching is done with ion-free water to remove dissolved organic acids during the incubation period while reducing salt levels in peat water. The peat soil was given 6.66 g of fertilizer N / pot, 4.86 g P_{2}O_{5} / pot and 3.85 g K_{2}O / pot and planted with rice seeds that were one month old each of 4 plants per pot. The soil condition of water saturated was maintained for 5 days until the plants recovered. Subsequently carried out flooding as high as about 5 cm and dried again to water saturated condition a day before and after the second N fertilization (3 weeks after planted) and the third N fertilization (5 weeks after planted) and being dried again in water saturated condition until the seed filling is perfect.

3. Results and Discussion

The results showed the effect of zeolite mineral, volcanic sand, mixture of zeolite volcanic sand and sea water on the bulk density of peat soil and the growth of rice plants observed after harvest.

The provision of volcanic sand and zeolite + sand mixture significantly increase the number of vegetative tillers per clump while giving 1500 ml of sea water significantly suppress growth of the number of vegetative tillers per clump. As for the number of vegetative tillers, the provision of volcanic sand, a mixture of zeolite + volcanic sand and the provision of 500 ml seawater also gives almost the same effect on the productive tillers per clump and the interaction between these two factors also has a significant increased on the number of productive tillers, as showed in Table 1 and Table 2 and their growth performance in Figure 1 and Figure 2.
Table 1. Number of vegetative tillers after vegetative stage

| Treatments                | Sea Water | Means    |
|---------------------------|-----------|----------|
|                           | 0 ml      | 500 ml   | 1000 ml  | 1500 ml  |
| Control                   | 7.33      | 7.00     | 5.67     | 2.67     | 5.67 b   |
| Zeolite                   | 8.33      | 13.33    | 6.00     | 4.33     | 8.00 ab  |
| Volcanic sand             | 14.00     | 13.67    | 15.67    | 4.00     | 11.83 a  |
| Zeolite + Volcanic sand   | 16.00     | 16.67    | 8.00     | 6.33     | 11.75 a  |
| **Means**                 | **11.42 a**| **12.67 a**| **8.83 ab**| **4.33 b**|

Table 2. Number of productive tillers after generative stage

| Treatments                | Sea water | Means    |
|---------------------------|-----------|----------|
|                           | 0 ml      | 500 ml   | 1000 ml  | 1500 ml  |
| Control                   | 4.00 f    | 5.33 ef  | 6.00 ef  | 3.33 f   | 4.67 b   |
| Zeolite                   | 6.00 ef   | 8.33 de  | 3.33 f   | 3.00 f   | 5.17 b   |
| Volcanic sand             | 15.67 a   | 11.67bed | 12.67abc | 4.33 f   | 11.08 a  |
| Zeolite + Volcanic sand   | 10.00 bcd | 15.00 ab | 6.00 ef  | 4.00 f   | 8.75 a   |
| **Means**                 | **8.92 ab**| **10.08 a**| **7.00 b**| **3.67 c**|

Figure 1. The growth of rice plant, 40 days after planted
The dry weight of the shoot and plant roots when harvesting both mineral and sea water give a significant effect. The provision of volcanic sand and zeolite + volcanic sand mixture increases the dry weight of the shoot and roots, whereas the provision of 1500 ml of seawater actually decreased the amount of shoot weight and plant roots, especially against to the control, as showed in Table 3 and Table 4.

Table 3. Dry weight of the shoots plant after harvesting

| Treatments               | Sea water     | Means     |
|--------------------------|---------------|-----------|
|                          | 0 ml          | 500 ml    | 1000 ml  | 1500 ml  |
| Control                  | 4.75          | 10.32     | 10.53    | 8.63     | 8.56 b   |
| Zeolite                  | 21.93         | 33.24     | 5.41     | 8.96     | 17.39 ab  |
| Volcanic sand            | 38.29         | 28.42     | 28.39    | 10.17    | 26.32 a   |
| Zeolite +Volcanic sand   | 41.62         | 28.39     | 20.42    | 14.72    | 26.29 a   |
| **Means**                | **26.65 a**   | **25.09 a**| **16.19 ab** | **10.62 b** |

Table 4. Dry weight of the roots plant after harvesting

| Treatments               | Sea water     | Means     |
|--------------------------|---------------|-----------|
|                          | 0 ml          | 500 ml    | 1000 ml  | 1500 ml  |
| Control                  | 4.96          | 1.38      | 3.12     | 1.70     | 2.79 b   |
| Zeolite                  | 5.22          | 6.07      | 1.16     | 3.99     | 4.11 ab  |
| Volcanic sand            | 15.35         | 10.36     | 5.29     | 2.95     | 8.49 a   |
| Zeolite +Volcanic sand   | 11.18         | 10.84     | 3.98     | 2.61     | 7.15 a   |
| **Means**                | **9.18 a**    | **7.16 ab**| **3.39 bc** | **2.81 c** |

Figure 2. The growth of rice plant, 64 days after planted
The provision of volcanic sand and zeolite + volcanic sand mixture has a significant effect in increasing the value of bulk density of peat soil at harvest as showed in Table 5, while the influence of seawater on the bulk density has no significant effect.

| Treatment                        | Bulk Density (BD) |
|----------------------------------|-------------------|
| Control                          | 0.18 c            |
| Zeolite                          | 0.21 bc           |
| Volcanic sand                    | 0.33 a            |
| Zeolite + Volcanic sand          | 0.31 ab           |

Dissolved salts present in seawater can affect the soil directly by replacing cations that can be exchanged on the surface of soil colloids and indirectly through their effects on microbes, root activity and physical properties of soil colloids [14]. IR-64 rice variety grown on tidal peat land (marine peat) with given high levels of iron ameliorant gave the highest yield compared to those planted on transitional peat (brackish peat) and peat which were only affected by fresh water (fresh water peat) at Kalimantan Tengah, Indonesia [15].

4. Conclusion
The application of volcanic sand and a mixture of zeolite + volcanic sand then leached with 500 ml sea water increased the number of vegetative tillers, productive tillers per clump, shoot dry weight and plant roots, in contrast when leached by sea water of 1500 ml reduced the number of vegetative tillers, productive tillers, shoot and roots plant dry weight.

References
[1] Halim A P K S 1989 Perbaikan tanah gambut pedalaman melalui peningkatan kejenuhan basa untuk budidaya tanaman kedelai [Improvement of inland peat soils through increased base saturation for soybean plant cultivation] Proc. Sem. Tanah Gambut Untuk Perluasan Pertanian [Peat Soil for Agricultural Extension] (medan) (Medan, Indonesia: Faculty of Agriculture, Universitas Islam Sumatera Utara) p 80 – 110
[2] Prasetyo T B 1996 Perilaku Asam-Asam Organik Meracun Pada Tanah Gambut yang Diberi Garam Na dan Beberapa Unsur Mikro Dalam Kaitannya Dengan Hasil Padi [Behavior of Toxic Organic Acids in Peat Soils Given Salt and Some Micro Elements in Relation to Rice Results] [Dissertation] (Bogor, Indonesia: Institut Pertanian Bogor)
[3] Salampak 1999 Peningkatan Produktivitas Tanah Gambut yang Disawahkan Dengan Pemberian Bahan Ameliorant Tanah Mineral Berkadar Besi Tinggi [Increased Productivity of Peat Soils for rice land with High Iron Iron Mineral Soil Ameliorant] [Dissertation] (Bogor, Indonesia: Institut Pertanian Bogor)
[4] Mario D M 2002 Peningkatan Produktivitas dan Stabilitas Tanah Gambut Dengan Pemberian Tanah Mineral Yang Diperkaya Oleh Bahan Berkadar Besi Tinggi [Increasing the Productivity and Stability of Peat Soils with Mineral Soil Giving Enriched by High Iron-Based Materials] [Dissertation] (Bogor, Indonesia: Institut Pertanian Bogor)
[5] Rumbang N 2003 Polyphenol in peat soil and growth and yield of rice (Oriza sativa L.) Proc. of Int. Symp. on Land Management and Biodiversity in South East Asia. (Bali) (Sapporo, Japan: Hokkaido University) p 200 – 7
[6] Suwarno 2003 Utilization of steel slag in wetland rice cultivation on peat soil Proc. of Int. Symp. on Land Management and Biodiversity in South East Asia. (Bali) (Sapporo, Japan: Hokkaido University) p 180 – 4
[7] Iskandar, Djajakirana G and Marolop R 2003 The use of fly ash as ameliorant to improve the chemical properties of peat soil in Pulau Muda, Riau Province Proc. of Int. Symp. on Land
Management and Biodiversity in South East Asia. (Bali) (Sapporo, Japan: Hokkaido University) p 215 – 9

[8] Suastika I W, Sabiham S and Suriadikarta D A 2006 Pengaruh pencampuran tanah mineral berpirit pada tanah gambut terhadap pertumbuhan dan hasil tanaman padi [The effect of mixing of pyritic mineral soil on peat soil on the growth and yield of rice crops] JIPI 8 2 p 99 – 109

[9] Musta B, Erfen H F W S and Tahir S 2008 Geochemical characterization of volcanic soils from tawau sabah Bulletin of the Geological Society of Malaysia 54 p 33 – 6

[10] Mumpton F A 1985 Using Zeolit for Agriculture (Brockport, New York: Department of the Earth Sciences, State University College) chapter 8 p 127 – 58

[11] Ilahude A G 1999 Pengantar ke Oseanologi Fisika [Introduction to Oceanic Physics] (Jakarta, Indonesia: Pusat Penelitian dan Pengembangan Oceanologi, Lembaga Ilmu Pengetahuan Indonesia [Research and Development Center of Oceanology, Indonesian Institute of Sciences])

[12] Little T M and Hills F J 1978 Agricultural Experimentation Design and Analysis (New York: John Wiley and Sons)

[13] Gomez K A and Gomez A A 1984 Statistical Procedures for Agricultural Reseach. 2nd Edition (New York: John Wiley and Sons)

[14] Abrol I P, Yadav J S P and Massoud F I 1988 Salt-affected soils and their management FAO Soils Bulletin 39

[15] Sabiham S 2010 Properties of Indonesia 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) (Bogor, Indonesia: Indonesian Soil Research Institute) p 205 – 16