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EFFECTS OF SURFACTANT AND AMELIORANT ON EFECTIVENESS OF P FERTILIZER ON HYDROPHOBIC PEAT FROM CENTRAL KALIMANTAN

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Abstract

In its natural state, peat is hydrophilic and able to absorb large quantities of water. On exposure to the sun, peat becomes slightly like coffee grounds and is showing hydrophobic properties. which is difficult to re-wet. It has unattractive physical and chemical properties and become slightly susceptible to erosion. In addition, peat has been known to have low P availability and P retension capacity Peat soils occupy a vast area in Indonesia which is approximately account for half of the world's tropical peat. Further, in some areas, the peat indicated hydrophobic in nature may be due to the unproper management e.g. slash and burning, exessive drainage. Problems related to hydrophobic properties of peat may be partially solved by applying surfactant and soil ameliorant, however very few research have been conducted in Indonesia on this topic.

The aim of this research is to study the influence of three kinds of surfactants (nonionic, anionic and cationic) and three ameliorants (lime, manure and fertilizers) to increase the P retention and to restore hydrophilicity of peat. A randomized design with four factors was replicated three times in a greenhouse experiment at the Gadjah Mada University, Yogyakarta. The first factor was the kind of peat (degraded and non-degraded peat). The second factor was the kind of surfactant. Three surfactants were used, i.e. anionic surfactants (laurel sulphate), nonionic surfactant (tween 80) and cationic surfactants (detergent solution). The third factor was the addition of ameliorants which were added to the pots of non-degraded peat and to the pots of degraded peat with and without surfactants. The fourth factor was phosphate addition which was added to the pots of non-degraded peat and to the pots of degraded peat with and without surfactants. The results showed that hydrophobic peat is more acidic, has a lower CEC, higher total acidity and a greater number of carboxyl and phenolic-OH groups than hydrophilic peat. Addition of surfactants and ameliorant significantly increased availability and effectiveness of P fertilizer on restored peat.. There was a significant and positive effect of the rates of P application and types of surfactants on effectiveness of P fertilizer.

Keywords: hydrophobic peat, surfactants, ameliorants, phosphate retention, P fertilizer effectiveness

Introduction

Peat is a spongy substance with a colloidal character that enables it to retain considerable quantities of water (Driessen and Rohimah, 1976). If peat is dried to the extent in which the adsorptive water is lost, irreversible change occurs in the colloidal structures, resulting in a marked and permanent reduction of the water retention capacity (Driessen and Rohimah, 1976). Dried peat is also hydrophobic, and it is difficult to rewet. The water loss and a presumed change in colloidal properties lead to considerable and irreversible shrinkage in the peat. Then peat becomes granular powders with unattractive physical and agricultural properties and a high propensity for erosion. Peatlands in Indonesia cover an area of approximately 27 million hectares. Those are located mostly in Sumatra, Kalimantan, and Irian Jaya (Radjagukguk, 1995). However, the peat in these areas has become hydrophobic due to the missmanagement such as overdrained and burning and then has been abandoned by farmers. This is a serious problem in Indonesia. This problem has affected 60-70% (600,000-70,000 ha) of the reclaimed land by "the new one million hectare Mega Rice Project in Central Kalimantan" (Maas, 2000) and 32,500 ha in Belawan, South Kalimantan (Soetikno *et al.*, 1998).

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When the water content of peat is reduced to level substantially below 50%, it becomes progressively more difficult to rewet the solids. Drying apparently involves other changes than the simple reversible loss of water molecules. This commonly observes that loss of rewettability still lacks an adequate verifiable scientific rationale, although numerous speculative explanations have been offered (Fuchsman, 1986). Problems with hydrophobic peat may be partially solved by using surfactants, but little researches have been performed in Indonesia about this topic. However, products, which potentially modify water surface tension and facilitate peat rewetting, have been identified (Michel *et al.*, 1997; Kostka, 2000; Dekker *et al.*, 2001; Sri *et al.*, 2009a, Sri *et al.*, 2009b).

In addition to problems with rewetting, peat soils are reported to have low P retention capacity (Maas *et al.*, 1991; Suryanto, 1994; Salampak, 1999). Use of compounds that can absorb P is a way to increase the P retention capacity of peat soils. The effectiveness of P adsorpable compounds is determined by the valence and atomic number of the adsorbent elements (Schnitzer and Skiner, 1967; Baes and Bloom, 1988; Zhu and Alva, 1993) and the anion to which it is paired (Bolt, 1967; Ray *et al.,* 1986; Maas *et al.*, 1991; Tan, 1998). The P retention capacity and P supplying capacity of peat soil can be increased through the use of Cation Bridge made of ameliorant (Suryanto, 1994; Maas *et al.*, 1997; Salampak, 1999). Ameliorant materials that have been used to increase the P retention of peat due to cation bridges include ash, lime and manure (Adi Jaya *et al.*, 2001; Suryanto, 1994, Masganti, 2004). Ameliorant materials having many cations can be used to strengthen the bond of phosphate ion and organic compound, so that it is not easily leached.

In order to solve two problems associated with hydrophobic peat, the irreversible drying and poor P retention, influence of three kinds of surfactants (nonionic, anionic and cationic surfactants) on rewetting and that of three ameliorants (lime, manure and fertilizers) on the P retention of hydrophobic peat were studied.

Materials and Methods

Peat Samples

Degraded and non-degraded hydrophilic peat samples were collected from the top 200 mm of the soil profile at Berengbengkel, Central Kalimantan. The samples were mixed and dried in an oven 50°C for 10 h so that their moisture content about 20 %. This treatment created a stable water repellency that did not change with time after the contact with water. Some of the non-degraded peats were left untreated to act as a control medium.

Experimental Design

A randomized design with four factors was replicated three times in a greenhouse at the Universitas Gadjah Mada. The experiment was conducted in a greenhouse. The first factor was the kind of peat and polyethylene pots, 300 mm in diameter, were filled with 1 kg oven-dried or non-degraded peat per pot. The second factor was the kind of surfactant. Three surfactants were used, i.e. anionic surfactants (laurel sulphate), nonionic surfactant (tween 80) and cationic surfactant (detergent solution). These surfactants were mixed with the degraded peat at 5 mg per g peat. Post of degraded peat without a surfactant was also prepared to act as a control for the addition of surfactant. The third factor was the addition of ameliorants which were added to the pots of non-degraded peat and to the pots of degraded peat with and without surfactants. Lime was added by using formula = 0.5 x total acidity, while manure is applied on the same level i.e. 20 $ton.ha^{-1}$ (Suryanto, 1997). The base fertilizer applications were 135 kg.ha-1 N from urea, 71,9 kg K.ha-1 from KCl, Cu (2 $\mu g.g^{-1}$) from $CuSO_4 5H_2O$, Mn (1 $\mu g.g^{-1}$) from $MnSO_4H_2O$, Zn (1 $\mu g.g^{-1}$) from $ZnSO_4 7H_2O$ and B (2 $\mu g.g^{-1}$) from H_3BO_3. The fourth factor was phosphate addition, there were added to the pots of non-degraded peat and to the pots of degraded peat with and without surfactants. Phosphate was added at 0%, 50 %, 100 % and 150 % of P recommendation for corn (160 $kg.ha^{-1}$). In order to maintain the moisture content of the soil at approximately field capacity throughout the duration of the experiment, distilled water was added daily. After 2 weeks incubation, acidity was measured by titration with HCl (Tan, 1996), carboxyl group by $Ca(CH3COO)_2$ extraction and phenolic-OH calculated by the differences between acidity and carboxyl group contents. Available P was measured by Bray II extraction (Tan, 1996). The P fertilizer effectiveness can be calculated by formula:

$$\text{P fertilizer effectiveness (\%)} = \frac{\mu g.g^{-1}\,P\ available\ after\ treatment - \mu g.g^{-1}\,P\ initial}{\mu g.g^{-1}\,P\ addition} \times 100$$

Soil pH was determined in 1: 5 soil/water suspensions, organic matter content was determined by the dry combustion method (Nelson and Sommers, 1982). Soil water content was determined using the gravimetric method with oven drying as described by Tan (1996) and the water-holding capacity was calculated by the difference between the water content at saturation and at complete dryness, and cation exchange capacity was measured by NH_4OAC pH 4 (Tan, 1996).

Statistical Analysis

Data were reported as means ± standard deviations of three replicates. Analysis of variance and Duncans Multiple Range were used, with least significant difference of means (5%).

Result and Discussion

Peat Material Properties

Table 1. Peat material properties of peat from Berengbengkel

Peat sample	pH H_2O	Organic matter %	CEC cmol(+)kg^{-1}	Total acidity cmol(+)kg^{-1}	—COOH cmol(+)kg^{-1}	—OH cmol(+)kg^{-1}
Hydrophilic peat	3.95	98.94	241.34	13.59	2.44	11.59
Hydrophobic peat	3.71	98.31	94.42	11.79	1.97	9.82

Physical Properties

Table 2. Physical properties of peat from Berengbengkel, Central Kalimantan

Peat material	Soil moisture content % (w/w)	Ash content %	Contact angle (^{0})	Pirophosphat index	Bulk density g/cm^3	maturity
Hydrophilic peat	249.98	1.86	69.8	10 YR 4/3	0.18	Saprist
Hydrophobic peat	26.60	1.65	113.1	10 YR 4/3	0.21	Saprist

Chemical properties of hydrophobic and hydrophilic peat are shown in Table 1. These data show that hydrophobic peat is more acidic, has a lower CEC, higher total acidity and a greater number of carboxyl and phenolic-OH groups than hydrophilic peat. The differences in the physical properties are shown in Table 2. Hydrophilic peat is able to hold ~250% water compared to hyrdrophobic peat which can only hold ~27% water. Other differences include contact angle. Drying of peat has a significant effect on peat properties. Reduction on soil moisture content by drying peat results in a decrease in total acidity, carboxylic and phenolic-OH groups. This is also proved by Masganti *et al.*, (2002). Carboxylic and phenolic-OH groups have polar properties and, being hydrophilic, they react strongly with water in natural hydrophilic peat. Sri Nuryani Hidayah Utami *et al.*, (2009a) also published their finding using infrared spectra about the decreasing sum of COOH and phenolic-OH group on hydrophobic peat from Kelampangan, Kalimantan. In studies using IR analysis, the region between 3020 and 2800 cm^{-1} is often considered to reflect hydrophobic properties of SOM. Thus, Chapman *et al.* (2001) assigned the presence of vibration bands in 3000–2800 cm^{-1} region to waxes for peat samples. Gressel *et al.* (1995) used the region around 2930 cm^{-1} in spectroscopic study of litter material as evidence to suggest that its character under pine is more aliphatic compared to oak litter

Addition of Surfactants

Three commercial surfactants were used in this research, i.e. anionic surfactants (laurel sulphate), nonionic surfactants (tween 80) and cationic surfactant (detergent solution). Surfactants slightly increase EC, total acidity, carboxylic and OH group and cation exchange capacity of hydrophobic peat, but not for the pH H2O. There is no significant difference effect among the three surfactants.

Table 3. Peat properties after surfactant addition

Peat material	pH	EC	Total acidity cmol(+)kg^{-1}	Carboxylic groups cmol(+)kg^{-1}	Phenolic-OH groups cmol(+)kg^{-1}	CEC cmol(+)kg^{-1}
Natural hydrophilic peat	3.78a	45.54ab	12.13a	0.16a	11.97a	234.54a
Hydrophobic peat	3.87a	76.70a	8.03b	0.44ab	7.59b	197.93abcde
Hydrophobic peat + anionic surfactant	3.69a	59.99ab	9.00b	0.91b	8.09b	201.92abcd
Hydrophobic peat + nonionic surfactant	3.67a	45.64ab	10.20ab	0.54ab	9.66b	218.44abc
Hydrophobic peat + cationic surfactant	3.8a	44.95ab	9.32b	0.88b	8.44b	213.17abc

Rewetting ability refers to how rapidly a root medium absorbs water, and thus reaches its potential for maximum available water-holding capacity, with minimal leaching. The state of decomposition of the peat or bark may also affect the ability to rewet after drying. Older, more degraded peat contains relatively high amount of humic acid. Humic acid plays an important role in the lime requirement and the cation exchange capacity of peat. However, if degraded peat is allowed to become excessively dry, the humic acid may form hard granules that have lost their initial capacity to absorb water and react on the peat adsorption. Surfactants are lowering surface tension of the liquid phase, and the magnitude of the effect was strongly dependent on treatment rate.

P fertilizer efficiency

The biggest fertility problem of native ombrogenous peat are its low content of P available, and its small retention potential for phosphate, because of the adverse affinity of negatively charge peat for the phosphate ions. In his study on the physical properties of peat in relation to their rewetting properties, Pohan (1991) proved that electrolyte treatment could also change the physical characteristic of the peat and influence the water adsorption capacity. The higher the decomposition degree of the peat, the higher its bulk density and its wetting contact angle, and the lower its capillary rise and its total. According to Suryanto (1994), he argued that the longer reaction of the P fertilizer and peat materials, the less number of P carried by the leaching water. The longer contact between P fertilizer and peat colloid materials changes the status of the bound between peat colloid and P anion (Bloom, 1981; Stevenson, 1994), so the amount of P fertilizer covered by the peat materials becomes larger. Hydrophobic peat has a higher contact angel which makes it shorter contact between fertilizer and peat colloid materials. The addition of surfactants increases P available significantly.

Surfactants and ameliorant significantly increase P available in peat soil. There is a significant difference effect of rates of P application and kinds of surfactants. Phosphate retention capacity and P supplying capacity of the peat material is strongly determined by type of cation and anion used as a P adsorbent compound. As reported by Masganti (2003), Ca results in highest P retention capacity and P supplying capacity of the peat material.

Table 4. Influence of surfactants and ameliorants on the available P of peat

	Level of P addition			
	0%	50%	100%	150%
Peat material	Available P (µg P.g^{-1})			
Natural hydrophilic	11.60d	56.86c	93.97a	83.22a
Hydrophobic peat	15.39d	51.62c	51.62c	88.43a
Hydrophobic peat + anionic surfactant	16.00d	52.87c	82.95ab	97.11a
Hydrophobic peat + nonionic surfactant	6.95d	56.90c	57.95c	91.02a
Hydrophobic peat + cationic surfactant	11.56d	59.43bc	76.00abc	92.40a

Influence of surfactants and ameliorants on the P fertilizer Effectiveness

As a result on the increasing P available in hydrophobic peat which had been added by surfactants and ameliorants, P fertilizer effectiveness increased significantly.

Table 5. Influence of surfactants and ameliorants on the P fertilizer effectiveness

	Level of P addition			
	0%	50%	100%	150%
Peat material	P fertilizer efficiency (%)			
Hydrophilic peat		21.25cd	15.01cd	11.88d
Hydrophobic peat		25.37bc	12.73d	16.46cd
Hydrophobic peat + anionic surfactant		38.11a	20.47cd	18.57cd
Hydrophobic peat + nonionic surfactant		33.48ab	17.43cd	18.80cd
Hydrophobic peat + cationic surfactant		36.08a	23.12c	18.54cd

The result showed that surfactants and ameliorants increase P fertilizer effectiveness of hydrophobic peat. There was a slightly significant difference effect among three surfactants. The highest efficiency of P fertilizer (38.11%) was obtained on hydrophobic peat + anionic surfactant fertilized with 80 kg.P.ha^{-1} The P fertilizer effectiveness of the experiments showed low value because it used sulphate compounds ($CaSO_4$) and not using carbonate, which allowed the pH of the still-low peat soils were exhibited the availability of P.

Conclusion

Hydrophobic peat is more acidic, has a lower CEC, greater number of carboxyl and phenolic-OH groups than hydrophilic peat. Addition of surfactants slightly increase the CEC, number of carboxyl and phenolic-OH groups. Furthermore, Surfactants and ameliorant significantly increase P available in peat soil. There is a significant difference effect of rates of P application and kinds of surfactants. Thus, surfactants and ameliorants increase P fertilizer effectiveness of hydrophobic peat. The highest effectiveness of P fertilizer (38.11%) is obtained on hydrophobic peat + anionic surfactant fertilized with 80 kg.P.ha^{-1}.

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