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Chemical Properties of Peat Pore Water in Central Kalimantan with Special Reference to Vertical Profile

Akira HARAGUCHI[1], Sawahiko SHIMADA[2], SUWARNO[3], Midori AKIOKA[1], Kazuo YABE[4] and Hidenori TAKAHASHI[2]

[1] Faculty of Science, Niigata University, Niigata 950-2181, Japan
[2] Graduate School of Earth Environmental Science, Hokkaido University, Sapporo 060-0810, Japan
[3] Bogor Agricultural University, Jl.Raya Pajajaran, Bogor, 16144 West Java, Indonesia
[4] Sapporo School of the Arts, Minami-ku, Sapporo 005-0864, Japan

Abstract

We studied the chemical properties of peat pore water in the catchment of the Sebangau River, Central Kalimantan, Indonesia. We compared the chemical processes in tropical peat from Paduran in the lower catchment of the river and Bakung, Rasau, and Setia Alam Jaya in the upper catchment with those in temperate peat from Furen mire in eastern Hokkaido. The pH of the peat pore water in tropical peatland was lower than that in temperate peatland. The pH of the middle peat layer was lowest in the upper catchment of the river. This would be the combined result of precipitation at the peat surface and mineral supply from the underlying mineral layer. The pH of the bottom peat layer was lowest in the lower catchment of the river. This would be due to the oxidation of pyrite in the underlying mineral layer. The peat was constantly oxidative from top to bottom, although the redox potential decreased from top to bottom. This condition promotes the oxidation of pyrite.

Introduction

Peatland is the largest pool of carbon in the world, estimated to be 329-528 Pg, accounting for one-third of the whole soil carbon pool (Post *et al*., 1982; Immirzi *et al*., 1992; Schimel, 1995). Maltby and Immirzi (1993) estimated that 15% of global peatland carbon is in the tropics, mostly in Indonesian peat swamp forests. The peat swamp forests are decreasing rapidly because of development for agriculture. Carbon dioxide and methane produced in their decomposition are thought to contribute to global warming.

Although peat covers a considerable area of tropical wetlands (Anderson, 1983; Neuzil, 1997), not enough fundamental data have been obtained. The process of peat formation and the chemical and physical properties of the peat are closely related to the topography, geology, hydrology, and climate of a site. In this study we aimed to clarify the chemical properties of peat with special reference to the coastal-inland gradient in the location of peatlands along a river system. We also compared the chemical properties of peat between tropical and temperate regions.

Study Area

We surveyed four sites in the catchment of the Sebangau River, Central Kalimantan, Indonesia; Setia Alam Jaya, Bakung, Rasau and Paduran (Fig. 1). We also surveyed a site in Furen mire, eastern Hokkaido, Japan. Site characteristics are summarized in Table 1.

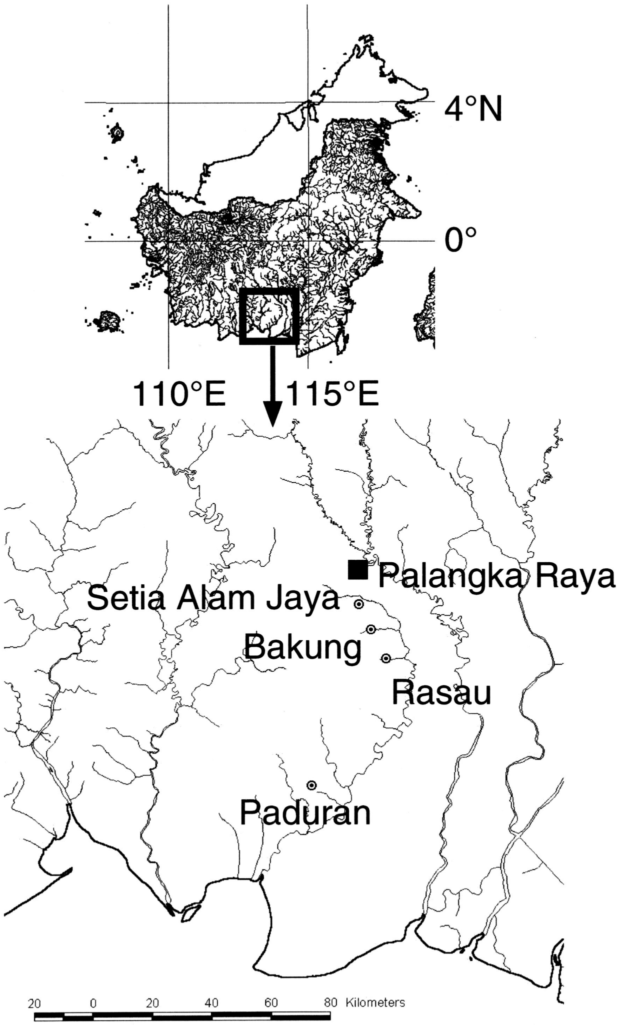


Fig. 1 The study area in Central Kalimantan.

Table 1. The characteristics of the study sites.

Area	Location	Land use	Sediment	Pyrite
Setia Alam Jaya	upper catchment of Sebangau River	natural forest	sand	absent
Bakung	upper catchment of Sebangau River	natural forest	sand	absent
Rasau	upper catchment of Sebangau River	natural forest	clay	absent
Paduran	lower catchment of Sebangau River	paddy field, natural forest	clay	present
Furen	lower catchment of Furen River, Hokkaido	mire	clay	absent

Setia Alam Jaya (2°18'S, 113°55'E) lies in the upper catchment of the Sebangau River. The site is ca. 2.5 km from the river at an altitude of ca. 12 m a.s.l. The land system at the site is classified as 'Peat Covered Sandy Terraces' (RePPProT, 1985). The forest at this site is dominated by *Calophyllum hosei*, *Palaquim cochlearifolium*, *Parastemon* *spicatus*, and *Combretocarpus rotundatus* (Shepherd *et al*., 1997).

Bakung (2°24'S, 113°56'E) lies near the Bakung River, a tributary in the upper catchment of the Sebangau River, at an altitude of ca. 12 m a.s.l. The land system at the site is classified as 'Permanently Waterlogged Plain' (RePPProT, 1985).

Rasau (2°30'S, 114°00'E) lies near the Rasau River, a tributary in the upper catchment of the Sebangau River, at an altitude of ca. 12 m a.s.l. The land system at the site is classified as 'Peat Basin/ Dome' (RePPProT, 1985).

Paduran (2°53'S, 113°46'E) lies near the Paduran Canal in the lower catchment of the Sebangau River at an altitude of ca. 9 m a.s.l. The canal was built in 1986-1988. The land system at the site is classified as 'Alluvial Floodplain between Swamps' (RePPProT, 1985). The study site was at Paduran I, one of three transmigration areas at Paduran.

Furen mire (43°17'N, 145°15'E) lies in the north-east of Japan and in the cool-temperate zone. The vegetation consists of ombrogenous Sphagnum mire and minerotrophic *Phragmites australis* (Cav.) Trin. ex. Steud. or *Alnus japonica* (Thunb.) Steud. community.

Materials and Methods

We took sample cores with an Eijelkamp peat sampler, which can collect 50 cm (400 cm^3) of core. Peat pore water was collected from bulk peat samples by filtering through nylon mesh (ca. 0.2 mm). The pH, electrical conductivity (EC), and redox potential (Eh) of the pore water were measured immediately after sampling.

Samples and measurements were taken in August 1998 in Paduran and Setia Alam Jaya, and in August 1999 in Bakung and Rasau.

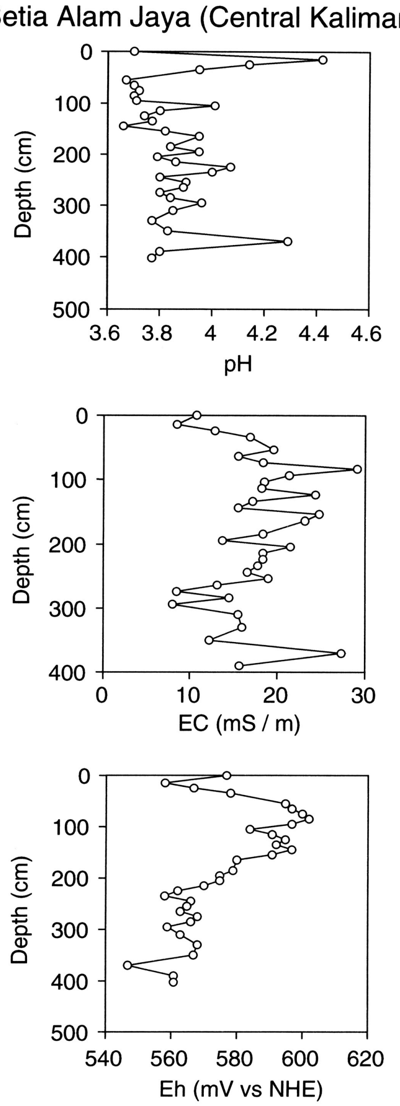
Results and Discussion

Setia Alam Jaya

We collected a sample core to a depth of 405 cm in natural forest. The pH of the peat pore water reached a maximum of 4.42 at a depth of 15 cm and decreased with increasing depth (Fig. 2). The pH fluctuated between 3.7 and 4.1 from 50 cm to the bottom, except at 370 cm. The EC was 10 mS m^{-1} at the peat surface; it increased to 29 mS m^{-1} at 85 cm, then decreased with increasing depth, but tended to increase again at the bottom. Eh increased from the surface to the depth of 100 cm and then decreased to the bottom. However, it remained >540 mV, and the peat was oxidative from top to bottom.

Bakung

We collected a peat core sample to a depth of 800 cm in natural forest just besides the Bakung River. The depth of the peat layer was 980 cm, and the bottom mineral layer was sand. The pH was ca. 5.5 at the surface; it reached a minimum of 3.12 at 290 cm, then increased to 5.02 at 800 cm (Fig. 3). The EC was 55 mS m^{-1} at the surface, decreasing to 10 - 29 mS m^{-1} below 25 cm. It tended to decrease with increasing depth, but increased again at the bottom. The Eh was 500mV at the surface, and it tended to decrease with increasing depth to a minimum of 420 mV at the bottom. The peat was oxidative from top to bottom.



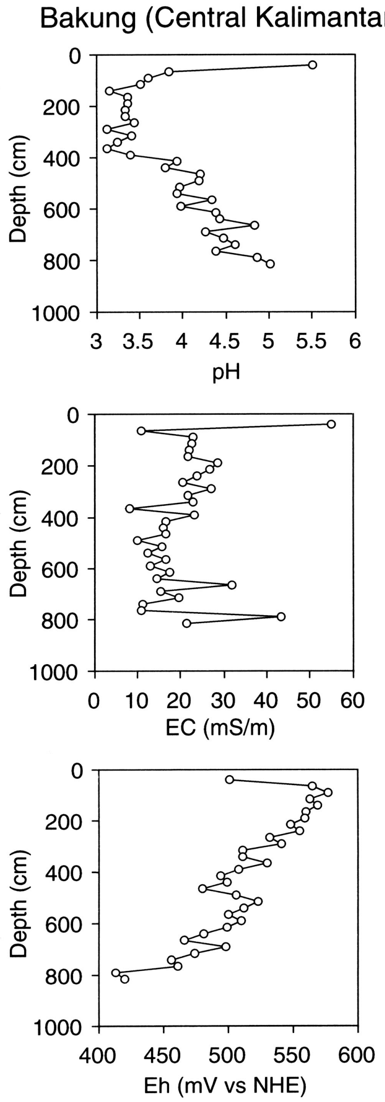


Fig. 2. pH (top), EC (middle) and Eh (bottom) of the peat pore water in natural forest a Setia Alam Jaya, Central Kalimantan.

Fig. 3. pH (top), EC (middle) and Eh (bottom) of the peat pore water in natural forest at Bakung, Central Kalimantan.

Rasau

We collected two peat samples. Site P1 was ca. 100 m from the Rasau River, and P2 was just beside the river. Both sites were in natural forest. The depths of peat were 200 cm at P1 and 400 cm at P2. The underlying mineral layer was clay at both sites. The pH of the peat pore water tended to decrease with depth (Fig. 4). The pH was 3.9 - 4.0 at the surface; it reached a minimum of 3.3 - 3.6 at 80 - 180 cm, and was 4.0 - 4.5 at the bottom of the peat layer. The EC tended to decrease from the surface to the bottom, although it increased slightly at the bottom. At P1, the EC was 28.4 mS m^{-1} at the surface and was 19.4 mS m^{-1} at the bottom. At P2, it was 10.2 mS m^{-1} at the surface and 6.8 mS m^{-1} at the bottom. The Eh tended to decrease from the surface to the bottom. Its minimum value was 414 mV at the bottom of P2, but the peat layer was rather oxidative from top to bottom.

Paduran

In the forest at Paduran (site P1), the depth of the peat was 95 cm, and the ground water table was at 0 cm. The pH, EC, and Eh of the peat pore water were 3.47 - 3.66, 25 - 95 mS m^{-1}, and 350 - 420 mV, respectively (Fig. 5). At the margin of the forest (site P2), the depth of the peat was 115 cm, and the water table was near the surface. The pH, EC, and Eh were 3.30 - 3.56, 31 - 108 mS m^{-1}, and 370 - 580 mV, respectively. On cultivated land (site P3), the depth of the peat was 40 cm, and the water table was at -10 cm. The pH, EC, and Eh were 3.63 - 3.91, 79 - 113 mS m^{-1}, and 200 - 410 mV, respectively.

At all sites, the pH tended to decrease from the surface to the bottom. The EC at Paduran was higher than inland; this would be the effect of sea salt, because the area is only 30 km from the coast. The EC and Eh tended to decline with increasing depth. The

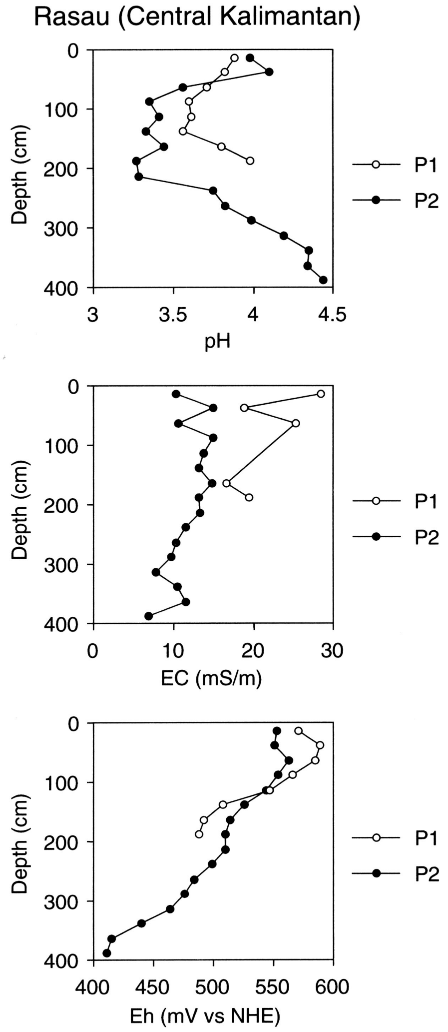


Fig. 4 pH (top), EC (middle) and Eh (bottom) of the peat pore water in natural forest at Rasau, Central Kalimantan. P1 is 100 m from the Rasau River, and P2 is just beside the river.

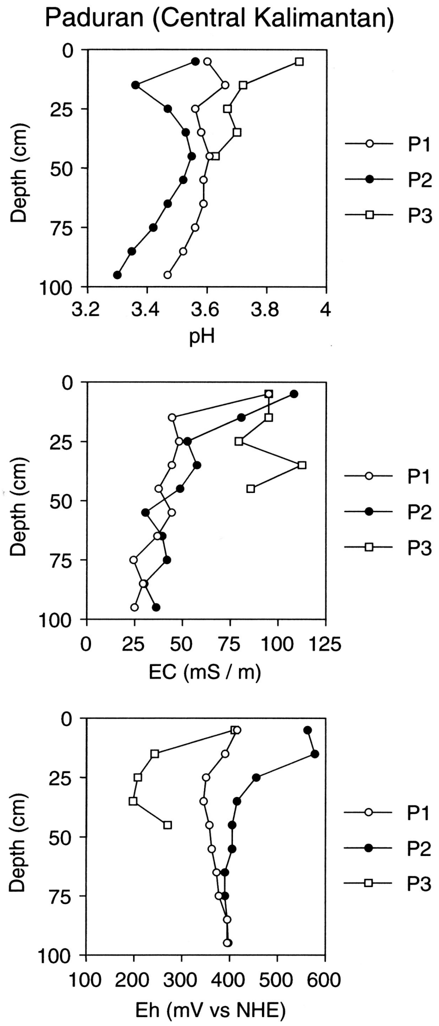


Fig. 5 pH (top), EC (middle) and Eh (bottom) of the peat pore water at Paduran, Central Kalimantan. P1, natural forest; P2, margin of forest; P3, cultivated land.

vertical profile of pH had different features from the profiles in the upper catchment of the river: the pH was lowest at the bottom of the peat layer. This would be due to the effect of sulfuric acid produced by the oxidation of the pyrite that occurs in the underlying mineral layers. The oxidative condition of the peat would enable this.

Furen mire, northern Japan

At Furen mire, a cool temperate peatlands in northern Japan, three peat core samples were collected: from the *Sphagnum* community (site L1), the *Alnus japonica* forest (site L10), and the *Phragmites australis* community (site L15). The depth of the peat was 2.0 - 3.0 m, and the underlying mineral layer was sand. The pH tended to increase with increasing depth. In the *Sphagnum* community, the pH was 5.26 at the surface and 5.61 at the bottom (Fig. 6). In the *A. japonica* forest, the pH was 5.48 at the surface and 5.91

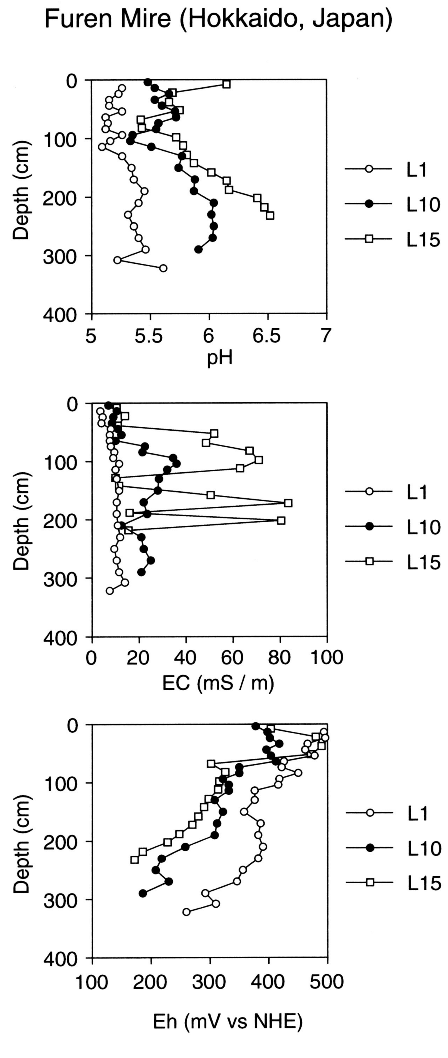


Fig. 6 pH (top), EC (middle), and Eh (bottom) of the peat pore water in Furen mire, north eastern Japan. L1, *Sphagnum* community; L10, *Alnus japonica* forest; L15, *Phragmites australis* community.

at the bottom. In the *Phragmites* community, the pH was 6.15 at the surface; it reached a minimum of 5.42 at 70 cm, then increased to 6.52 at the bottom. The EC tended to increase with increasing depth, although the fluctuations were extremely large, especially at L15. The redox potential tended to decrease with increasing depth. The Eh was 380 - 490 mV at the surface and 170 - 260 mV at the bottom. The Eh was lower than in the tropical peat.

Conclusion

The pH of the peat pore water in tropical peatland was lower than that in temperate peatland. The pH of the middle peat layer was lowest in the upper catchment of the Sebangau River. This would be the combined result of precipitation at the peat surface and mineral supply from the underlying mineral layer. The pH of the bottom peat layer was lowest in the lower catchment of the river. This would be due to the oxidation of pyrite underlying the peat layer. The peat was constantly oxidative from top to bottom. This condition promotes the oxidation of minerals, including pyrite.

Acknowledgements

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Boron Contents of Tropical Peat Soils in Southeast Asia

Koyo YONEBAYASHI and Hidekazu YAMADA
Faculty of Agriculture, Kyoto Prefectural University, Kyoto, Japan

Introduction

Boron (B) is one of the essential elements to vascular plants. B is essential for pollen tube growth and silk receptiveness to pollen (Marschner, 1986), and B deficiencies can reduce root growth rate (Bohnsack and Albert, 1977). The absorption of B by plant roots would differ from that of other ionized species since B is present in solution as undissociated H_3BO_3 (Barber, 1995). The availability of B is largely influenced by soil pH, being most available in the acidic pH range and less available with increasing pH, primarily due to the adsorption by soil colloids (Mahler *et al.*, 1988).

In general, B in soil can be divided into three categories: (i) B in primary minerals, such as tourmaline (borosilicate mineral), (ii) B adsorbed by soil constituents such as clay minerals, hydroxy oxide of Al and Fe, organic matter, and (iii) B in soil solution as boric acid and borate ions (Keren and Bingham, 1985).

In case of tropical peat soils, B will occur as complex with carbohydrate in peat materials or adsorbed by organic matter, and boric acid in soil solution being low pH of them. Little is known about B contents of tropical peat soils with respect to the sustainable availability of B to plants.

This study aimed to clarify the status of B in tropical peat soils of Southeast Asia.

Materials and Methods

Study sites

Peat soils were sampled from five soil profiles of coastal swamps in southern Thailand, southern Peninsular Malaysia, and Sarawak, Malaysia as shown in Table 1 (Yonebayashi *et al.*, 1994; Funakawa *et al.*, 1996). Four or five layers were sampled by 20 cm depth from the peat profiles.

Table 1. Study sites

Site	Location	Vegetation
MAT	Muar, Johor, Malaysia	Natural forest
BC-10	Bacho, Narathiwat, Thailand	Secondary forest
NM-1	Naman, Sibu, Sarawak	Secondary forest
NM-2	Naman, Sibu, Sarawak	Secondary forest
NM-3	Naman, Sibu, Sarawak	Secondary forest

Chemical analysis

Calcium, magnesium, sodium, potassium, iron, manganese, zinc, and copper contents were analyzed by atomic absorption spectroscopy after digestion by dry combustion. Phosphorus content was determined by colorimetry with molybdenum blue after digestion with nitric and sulfuric acids. Available B contents were determined for the extract with hot water and the extract with 2% mannitol-0.02M acetate buffer (pH4.5) solution. One gram of soil was placed in Teflon test tube and 8 ml of extract solution was added. The test tube was heated in block heater at 135°C, and refluxed for 15 min. The suspension was centrifuged and filtrated with 3 µm membrane filter. An aliquot of supernatant proceeded with ICP-AES determination of B.

Results and Discussion

Mean chemical composition of peat profiles analyzed in this study was shown in Fig.1. The N, P, and K contents decreased with soil depth, especially K content of deeper layer was very low and less than one third of that of surface layer. Ca and Mg contents were almost constant with soil depth and showed very low contents. Mean contents of Fe, Mn, Zn, and Cu were almost steady with soil depth and showed very low values. From the analysis of the distribution of heavy metals, as water soluble, calcium exchangeable, oxides, weakly chelated, strongly chelated, carbonates, sulfides, and nonextractable forms, major parts of Cu and Fe were complexed with humic substances or non-extractable form, and were not available to plants. Especially the low content of Cu of the surface soil was very severe for the plant growth.

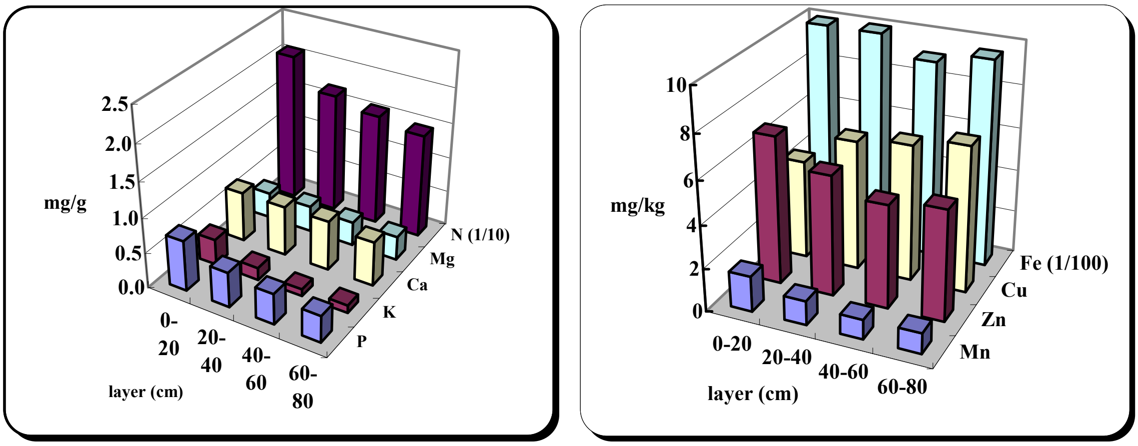

Fig. 1. Mean chemical composition of peat profiles analyzed.

For the study of B status in peat soils, two extraction methods were used. Both methods extract available B from soils. Hot water extractable B of surface soils of 0 to 20 cm depth were 0.04-0.56 mg kg^{-1} of soils and those of subsoils decreased with depth until 60cm except SA1 soil, as shown in Fig 2. And it was not detected in the subsoils of 40-60 cm depth except SA1. Mean contents of them for surface soils and subsoils of 40 to 60 cm depth were 0.26 and 0.02 mg kg^{-1}, respectively (Table 2).

Mannitol-acetate buffer extractable B ranged from 0.13 to 0.35 mg kg^{-1} for surface soils and from 0.03 to 0.20 mg kg^{-1} for subsoils. Mannitol-acetate extractable B content decreased with soil depth until 60cm and increased at 60 to 80cm layer in some soils (SA1, MAT, BC10) (Fig 3). Mean contents of them for surface soils and subsoils were 0.26 and 0.10 mg kg^{-1}, respectively (Table 2).

Mean content of hot water extractable B and mannitol-acetate extractable B of surface soil showed same value. Though the hot water extractable B of 40 to 60 cm is less than one tenth of that of surface soil, the mannitol-acetate extractable B of 40 to 60 cm is about one third of that of surface soil.

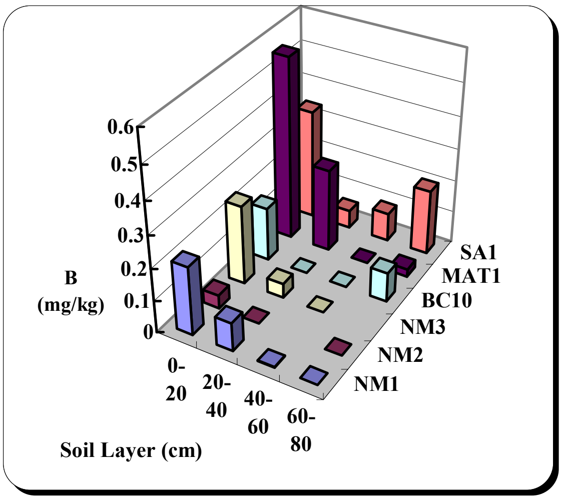

Fig. 2. Hot water extractable B content.

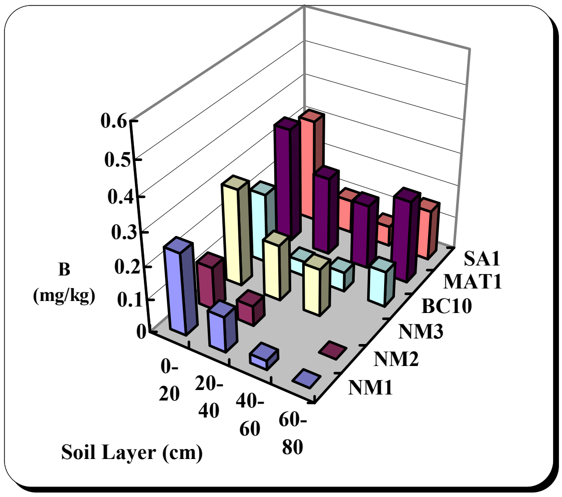

Fig. 3. Mannitol-acetate extractable B content.

Table 2. Mean contents of available soil B of tropical peat soils

Soil	Depth, cm	Hot water extractable B	Mannitol-acetate extractable B
		Average (range), mg kg^{-1}	
Surface soil	0 – 20	0.26 (0.04 - 0.56)	0.26 (0.13 - 0.35)
Subsoils	20 – 40	0.07 (0 - 0.26)	0.12 (0.05 - 0.24)
Subsoils	40 – 60	0.02 (0 - 0.09)	0.10 (0.03 - 0.20)
Critical level for plant		0.3 - 1.5	

Extraction of the air-dried soil with hot water would remove soluble B that was in soil solution under natural condition. The B in solution occurs as the undissociated acid H_3BO_3 under the low pH of peat soils. This extractable B is considered to be "readily available" B. Some of the B of peat soils in natural state seems to have coordinated to the cis-hydroxyl group of the carbohydrate in peat materials. At the extraction of the soils with mannitol solution, the cis-hydroxyl group of the mannitol forms the complex by coordinating to the boron. Therefore, extraction of the soil with mannitol-acetate buffer removes soluble plus adsorbed or complexed B. This extractable B was considered to be "total available" B.

Critical levels of hot water extractable B reported in the literature ranged from 0.3 to 1.5 mg kg^{-1} for various crops and soils (Barber, 1984). Readily available B was absolutely deficient in subsoils and was not sufficient even in surface soils of tropical peat soils. Mean content of total available B for subsoils was five times that of readily available B, but not sufficient to plant growth.

The B which deducted the readily available B from the total available B seems to be the carbohydrate complex. Most of the B in the surface layer soil is readily available form, and the carbohydrate complex is few. Total available B of the subsoil are under the half of the surface soil, and many of them is the carbohydrate complex, and the readily available B is very few. Though much peat of the subsoil is undecomposed, the B which coordinated in the carbohydrate of the plant tissue in decomposition process exists as potentially available form. Readily available B in the surface soil is the B which occurred by mineralization of the fallen litter at the soil surface, and the circulation of the boron is carried out between plant and surface soil as shown in Fig. 4. It seems to supply the B, which is necessary for the plant growth, barely by the circulation of readily available B in the surface soil, because the readily available B of the subsoil is extremely little. It is necessary to mind the supply of the B in agricultural development for the careless development cut off the circulatory system of the B.

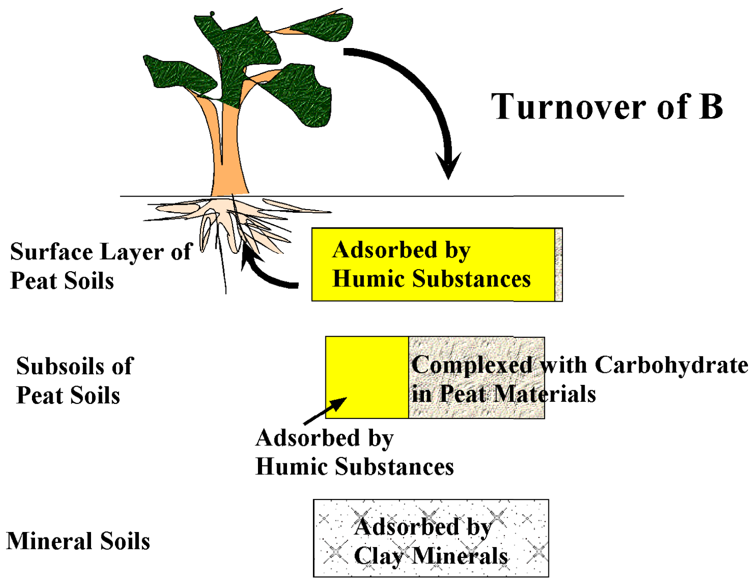

Fig. 4. Boron status in tropical peat soils.

Summary

Peat soils were sampled from coastal swamps in southern Thailand, southern Peninsular Malaysia, and Sarawak, Malaysia. Available B contents were determined for hot water extract and mannitol-acetate buffer extract.

Hot water extractable B of surface soils of 0 to 20 cm depth were 0.04-0.56 mg kg^{-1} of soils and those of subsoils decreased with depth. Mean contents of them for surface soils and subsoils of 40 to 60 cm depth were 0.26 and 0.02 mg kg^{-1}, respectively. Mannitol-acetate buffer extractable B ranged from 0.13 to 0.35 mg kg^{-1} for surface soils and from 0.03 to 0.20 mg kg^{-1} for subsoils. Mean contents of them for surface soils and subsoils were 0.26 and 0.10 mg kg^{-1}, respectively.

Critical levels of hot water extractable B reported in the literature ranged from 0.3 to 1.5

mg kg^{-1} for various crops and soils (Barber, S.A., 1984). Hot water extractable B means readily available B, which is absolutely deficient in subsoils and is not sufficient even in surface soils of tropical peat soils. Assuming mannitol-acetate extractable B intends total available B in peat soils, mean content of total available B for subsoils was five times that of readily available B, but not sufficient to plant growth.

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Microbial Biomass in Tropical Peat Soil

Kazuyuki INUBUSHI[1] and Abdul HADI[2]
[1]Faculty of Horticulture, and [2]Graduate School of Science and Technology,
Chiba University, Matsudo, Chiba 271-8510 Japan

Abstract

Microbial biomass plays three roles in soil; first as driving force of bio-elements such as C, N, P etc.; second as nutrient pools for plant production and; third as environmental monitor to detect impact on soil. We tried to measure microbial biomass in tropical peat soil in Sarawak, Malaysia and South Kalimantan, Indonesia by ATP and chloroform-fumigation extraction methods. Results of ATP measurements indicate that surface soil contained comparable amounts of biomass as cultivated arable soil, but deeper soil (<50 cm) also retained significant amount of biomass. On the other hand, chloroform-fumigation method failed to measure biomass probably due to high amount of extractable C and N in peat soil. Organic matter dynamics as affected by land-use change in tropical peat soil is discussed.

Introduction

Microbial biomass plays three important roles in soil. First as driving force of dynamics of bio-elements such as C, N, P etc.; second as nutrient pools for plant production, and third as monitor of soil environment to detect impact of changes in soil conditions as early indicator (Powlson *et al.*, 1987) which may be caused by land-use change, biomass burning and so on in tropical peatland. It has been estimated that the total area under tropical peat land is around 29 million ha over the world (Takai, 1997). Large portions of this tropical peat soil exists in the Borneo Island (Driesen, 1978; Takai 1997), the world third largest island and belong to three countries; Indonesia, Malaysia, and Brunei. There are, however, few reports dealing with tropical peat soil, particularly on microbial biomass, which play important role in dynamics of soil organic matter changes.

The organic matter in the peat soils is naturally decomposed slowly but continuously. Decomposition of organic matter is basically the degradation of complex organic compounds, converting by heterotrophs. The decomposition causes the loss of mass (commonly stated as ground subsidence) and releases by-products, such as CO_2 and methane, both being greenhouse gases, leading to the formation of a more stable peat soil. Since tropical peat land contains large amounts of soil nitrogen (Ismunadji and Soepardi, 1984; Driesen, 1978), it could be the source of nitrous oxide emission, another greenhouse gas as well as distracting stratospheric ozone layer.

The demands for peatland for agricultural and aquacultural uses have been increasing (Ahmad *et al.*, 1986; Radjagukguk, 1991; Kyuma, 1992). A large portion of the peatland in South Kalimantan was, for instant, reclaimed when a vast conversion of natural wetland into rice field and settlement occurred in this province (Moehansyah, 1988; MacKinnon *et al.*, 1996). Meanwhile, in Sarawak (Malaysia) much of peatland was drained excessively and cultivated to oil palm (Ahmad *et al.*, 1986; Inubushi *et al.*, 1998). The peat soil converted so far has proven to be an efficient rice producer as well as upland-field crops (Ismunadji and Soepardi, 1984; Radjagukguk, 1990).

The conversion of peatland always starts with the construction of drainage ditches in order to reduce the excess water that is commonly associated with natural peatland. Theoretically, the submerged (anaerobic) condition of the natural tropical peat soil is favorable for anaerobic bacteria, whereas oxic condition is favorable for aerobic microfauna. Therefore, both natural and converted tropical peat soil can potentially control the dynamics of nutrient in microbial biomass. However, there is no quantitative data on the microbial biomass in tropical peat soils. In addition, the mechanisms involved in the dynamics of greenhouse gases in tropical peat soil are poorly understood. Since the ecosystem of the peat land is very vulnerable and readily affected by human activities (Reddy and Patrick, 1993; Tay *et al.*, 1991), improper land management could lead to increase loss of land resource and hence could enhance environmental risks. Therefore a more detailed knowledge about the functioning of the ecosystem of peat soil is truly needed. This paper focused on the dynamics of microbial biomass in tropical peatland, as well as the proper approach to measure it.

Site Description, Materials and Methods

Soil samples were taken in the peatland of the Borneo Island comprised of four sites; one site in Sarawak, Malaysia; and three sites in South Kalimantan, Indonesia. In all sites, the peat soils were characterized by irregular complex of poorly decomposed woody materials down to at least 2 meter in depth. Surface soil was relatively dry in general for Sago palm plantation by the recent excess drainage in Sarawak. Their adjacent secondary forest was composed mainly of Alan (*Shorea albida*) and classified as Alan swamp forest. Peat soil in Amuntai, South Kalimantan was similar as Sarawak. However soils were wetter due to that the sampling was done in wet season. Sampling sites in South-Kalimantan were set according to land-use change. Detail site description in Kalimantan was described in Hadi and Inubushi (2000).

Soil samples (equivalent to 1-2 g oven dried soil) were taken from surface layer (0-20 cm) and deeper layers (20-40, 40-60, 60-80, 80-100 cm, for Sarawak). Microbial biomass in each soil sample was estimated by adenosine-5' triphosphate (ATP) (Jenkinson and Oades, 1979). Briefly, microbial cells were destructed by ultra sonic and ATP was extracted by tricholoroacetic acid. Then luciferine-luciferase mixture was added to the filtrated extract to see bioluminessence. Another standard method for soil microbial biomass measurement, chloroform fumigation-extraction methods (Brookes *et al.*, 1985), was also employed to peat soil in Sarawak. This method is based on cell-lysis after chloroform fumigation, extracted cell components after fumigation being quantified as carbon or nitrogen basis.

Results and Discussion

Soil chemical and physical properties

Composition pattern along with soil profile shows that unique organic acids were accumulated in tropical peat soil (Fig. 1). Soil densities changed from 0.12-0.13 g mL^{-1} at upper 40 cm to 0.02 g mL^{-1} below 40 cm which indicates changes of water table in this site, and these changes are corresponded with accumulations of sulfate and acetic acid at interface layer at 40 cm. Ground water contained large amount of dissolved carbon especially in the plantation field soil. Peatlands in this area were characterized by strong acidity; the pH values (measured with glass rod electrode after 1 h shaking with distilled water using a 1:5 (soil:water) ratio) were always below 5. Organic matter contents of peat layers (estimated by dry combustion method, Black *et al.*, 1965) lied between 331.2 and 946.9 g organic matter kg^{-1} dry soil. The contents of total nitrogen of peat layers (measured with method described by Black *et al.*, 1965) varied from 7.0 to 23.1 g N kg^{-1} dry soil.

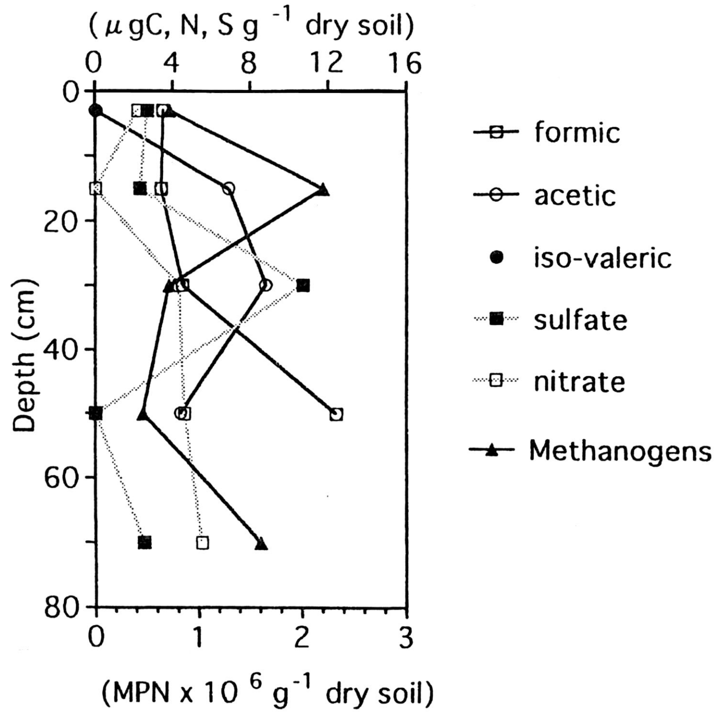

Fig. 1. Composition of organic acids and amount of sulphate, nitrate and methanogenic bacterial population along the peat soil profile in Sarawak, Malaysia (Inubushi *et al.*, 1998)

Soil microbial biomass

ATP content ranged from 5 nmol g^{-1} soil at the surface layer to about 3 nmol g^{-1} soil below 80 cm in Sarawak, decreasing gradually with soil depth (Fig. 2). These ATP contents indicate that living organisms were most abundant at surface layer, while more than half still remained in the deeper soil layers. Microbial activities of biomass such as CO_2 production, methane formation and oxidation were also not negligible in deeper soil layer (Inubushi *et al.*, 1998).

In Kalimantan, ATP seemed to decrease along with land-use history. A-1 (secondary forest) had highest ATP; 7.70 nmol g^{-1}, followed by A-2 (paddy soil after 2 year running); 7.09 nmol g^{-1}, then lowest at A-3 (rice-soybean rotation for 6 years); 1.89 nmol g^{-1}. This imply that microbial biomass depressed after changing peat land from secondary forest to arable land, although more careful examination should be carried out.

Fumigation-extraction method showed quite different soil profile as ATP. Microbial biomass accumulated at deeper layer rather than in surface layer (Figs. 2, 3). This may be due to the high amount of unstable soil organic matter remained in the peat

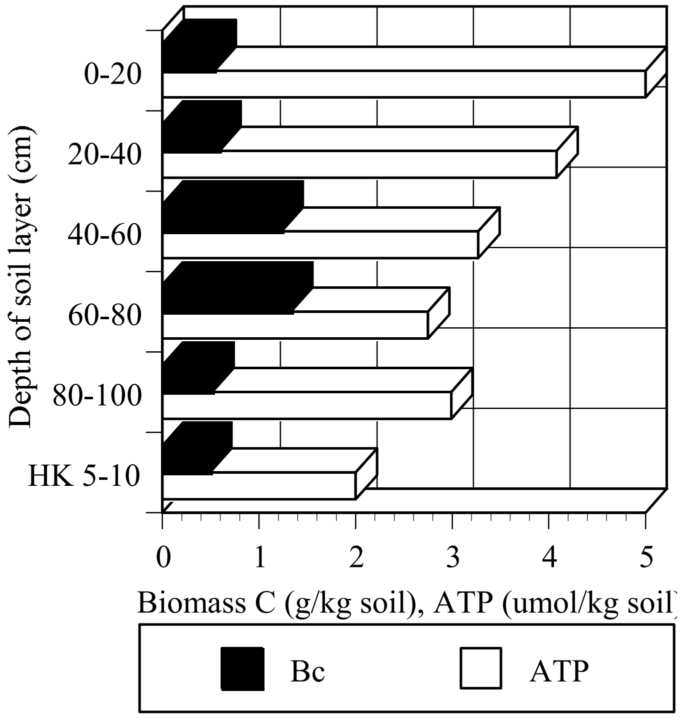

Fig. 2. Microbial Biomass in peat soil (Comparison of FE and ATP methods)

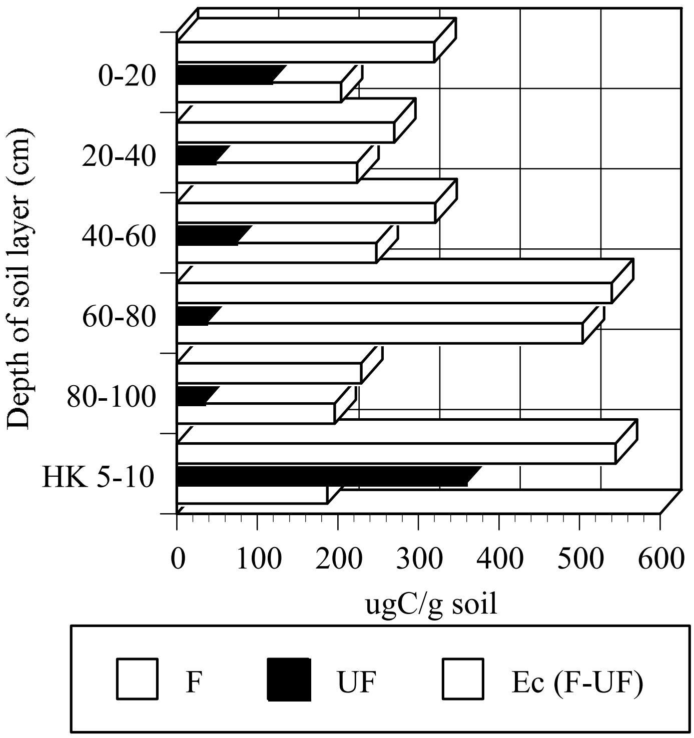

Fig. 3. Microbial Biomass in peat soil (Chloroform-fumigation extraction method)

soil, thus this method to determine microbial biomass" which was defined as the difference of extracted carbon or nitrogen in fumigated soil and unfumigated soil, could not be applicable to peat soil. Similar phenomena were also observed in compost which contain large amount of soluble organic matter (Rajbanshi and Inubushi, 1998).

Conclusion

Microbial biomass in tropical peat soil in Sarawak, Malaysia and South Kalimantan, Indonesia was measured by ATP and chloroform-fumigation extraction methods. Results of ATP measurements indicate that surface soil contained comparable amounts of biomass as cultivated arable soil, but deeper soil (<50 cm) also retained significant amount of biomass. On the other hand, chloroform-fumigation method failed to measure biomass probably due to high amount of extractable C and N in peat soil. Therefore further investigation by ATP method to see the effect of land-use would be required.

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Survey of Peat Soils in Sebangau-Kahayan Water-Catchment, Central Kalimantan for Laccase Producing Fungi and Their Organic Decomposing Ability

Typuk ARTININGSIH[1], Sehat Jaya TUAH[2], Edi MIRMANTO[1] and Mitsuru OSAKI[3]

[1] Research and Development Center for Biology, LIPI, Bogor, Indonesia.
[2] Department of Forestry, Faculty of Agriculture, University of Palangka Raya, Central Kalimantan, Indonesia.
[3] Laboratory of Plant Nutrition, Faculty of Agriculture, Hokkaido University, Sapporo, Japan.

Abstract

Eleven soil samples collected from different sites were screened for laccase production using guaiacol agar plates. The sites were native deep peat, burn deep peat, and abandoned area. Out of 105 isolates, only 30 isolates gave positive test for qualitative lignin degradation. Ten fungal isolates were selected further for quantitative study of wood/lignin degradation. The basidiomycetes proved to be better laccase producers and decomposers of organic-matter. These gave comparable results to a known white-rot fungus, *Coriolopsis* sp., *Fomes* sp., *Polyporus* sp., and *Amauroderma* sp. degraded wood sawdust causing a total weight loss of 12.8%, 12.3%, 8.7%, and 6.5% respectively, and lignin loss up to 12.4% in 30 days. The finding of three different activities of lignin degrading fungi were further selected for collecting the isolates.

Key words: degradation, guaiacol, lignin, white-rot fungus, *Polyporus* sp., *Fomes* sp., *Coriolopsis* sp., *Amauroderma* sp.

Introduction

Laccase is widely found in nature including in certain fungi that degrade lignin and is known to cause Bavendamn's reaction (Kawai *et al*., 1999). Fachraeus *et al.* (1958) was first detected laccase in the fruiting bodies of basidiomycetes fungi. Later, the development of Bavendamn test was of considerable significance for differentiating white- and brown-rot fungi. Many white-rot fungi produced extracellular phenoloxidase, which is shown by the formation of coloured oxidation products in the media containing phenol, such as guaiacol. Whereas brown-rot fungi lack such activity (Higuchi, 1982). Since then, various methods have been demonstrated to detect laccase production and attempts made to establish correlation with lignin degradation (Nobles, 1958; Kirk and Kelman, 1965; Harkin and Obst, 1973).

The phenomena of fungi in ligninolysis still remain unknown, however, laccase has been considered to be one of the important enzymes. It plays a key role in ligninolysis by causing its demethylation (Kirk and Chang, 1975). Its involvelment has been fairly substantiated by genetic studies in which laccase-less mutants were unable to degrade lignin (Ander and Eriksson, 1976). Microbiology of lignin degradation has revealed fungi, particularly the white-rot basidiomycete, to be an important group of organisms though certain brown-rot and soft-rot fungi and bacteria can cause ligninolysis to a limited extent (Ander and Eriksson, 1976).

Several numbers of fungi have been reported for laccase production and lignin degradation. The use of Bavendamn's reaction for determining the lignin-degrading abilities of fungi has also been reported. However, no study has been undertaken to directly isolate such fungi from peat ecosystem, which might better degrading species. Keeping this in view, a survey of soil samples collected from different areas to isolate laccase-producing fungi.

Material and Method

Collection of soil samples

Eleven soil samples were collected from three different sites of peat ecosystem in Sebangau – Kahayan water catchment, Central Kalimantan. The locations were a) native deep peat (6 plots namely A8, A10, D4, D6, G8, and G2), b) burn deep peat (5 plots namely A5, A7, D1, D9, G9), and c) abandoned area or native shallow peat (5 plots namely A8, D2, D4, G2, and J8). Each sample was taken in plastic bags from each site. The samples were stored at refrigerator until further processing.

Screening of laccase producing fungi

Soil sample (1 g) was suspended in 10 ml of 0.85% (w/v) physiological solution which was prepared freshly before used. The solution was agitated on a rotary shaker and allowed to settle.

PDA (Potato Dextrose Agar) medium containing guaiacol 0.5% (v/v) was inoculated with 0.1 ml soil suspension and incubated at 28°C for a maximum of 10 days. Population was counted everyday for each triplicate.

Each fungus was isolated and subcultures made as soon as browning of agar occurred until the isolates were pure. The isolate, which reddish brown colour under or around the colony, was recorded as a positive test for laccase and selected for further study. The selected isolate was tested to find any correlation between laccase production and lignin degradation by the methods of Bavendamm reaction and Sundman reaction.

Laccase activity (polyphenol oxidase)

From cultures on solid PDA, each selected fungus was inoculated into 50 ml of sterilized PDA broth containing lignin (indulin AT) 1% (w/v). The cultures were incubated stationarily at 28°C for 10 days. Triplicate flasks were applied for each fungus. After incubation, the filtrate was centrifuged at 10.000 g for 15 min at 4°C. Guaiacol was used as the substrate for measuring laccase from supernatant enzyme. The reaction mixture (5 ml) contained of 3.9 ml acetate buffer (10 mM, pH 5), 1 ml guaiacol (1.75 mM) and 0.1 ml enzyme extract. The mixture was incubated at 25°C for 2 h and the absorbance was read at 450 nm. In the blank, guaiacol was substituted by buffer. The formation of coloured products was taken as indicative of laccase activity, which was expressed in relative terms as colorimetric units per ml of the enzyme.

Degradation of wood sawdust

Ten fungal isolates were selected to study their wood (lignin) degrading ability since these gave comparatively better laccase activity. Three grams (dry weight) of wood sawdust was sterilized then inoculated with 15 ml of culture grown in PDA broth. Uninoculated substrate served as the control. After 30 days of incubation, triplicate samples were further processed. Ten ml of acetate buffer (10 mM, pH 5) was added to each flask then shaken for 20 min.

Identification of the isolated fungi

The isolated fungi with laccase potentiality were identified based on their colonial morphology by microscopical study. Fungi, such as *Gilmaniella* sp., and *Moniliella* sp. were identified according to Barron (1972) and Ellis (1976). Basidiomycetes were identified according to clamp connections, hyphal system, and spores (Breitenbach and Kranzlin, 1986).

Results and Discussion

The highest population of fungi found in 10–20 cm depths for native, burn, and abandoned area respectively (Fig. 1). It seems that fungal-population density is correlated to depths, which the more depths the density becomes less. This also revealed that the fungi isolated from those locations mostly are aerobic. The native deep peat may provide better source for fungal ecosystem, while that the abandoned area remains poor with reflects to low fungal density.

Using guaiacol and indulin AT as a source of lignin performed screening of fungi for laccase activity. In this study, it found 30 isolates gave positive results on laccase production although 4 isolates were a negative on guaiacol medium. All isolates, which gave positive results on guaiacol, lignin, and guaiacol-lignin medium respectively, were white-rot fungi (Table 1). Mostly brown-rot fungi gave a negative results on guaiacol, although some are positive on guaiacol-lignin medium (Table 2). On guaiacol medium, the three-imperfecti fungi isolated as follows *Paecillomyces* sp., *Gilmaniella* sp., and *Moniella* sp. showed positive reaction (Table 3.).

Table 1. Laccase production on lignin-guaiacol, lignin, and guaiacol media by white-rot fungi isolated from soil and their performance for Bavendamm and Sundman test (lignin degradation)

Culture No.	Type of fungus	Colour production on			Bavendamm test	Sundman Test
		Lignin guaiacol	Lignin	Guaiacol		
pAl-3	*Daedalea* sp.	+	+	+	+	+
pAl-15	*Fomes* sp.	+	+	+	+	+
pAl18-3	*Polyporus* sp.	+	+	+	+	+
BH4	*Polyporus* sp.	+	+	+	+	+
D6-1	*Polyporus* sp.	+	+	+	+	+
A9-3	*Coriolopsis* sp.	+	+	+	+	+
D4-1	*Stereum* sp.	+	+	+	+	+
D2-3	*Trametes* sp.	+	+	+	+	+
A3-2	*Phanerochaete* sp.	+	+	+	+	+
D1-2	*Lenzites* sp.	+	+	+	+	+
G2-1	*Amauroderma* sp.	+	+	+	+	+
A7-2	NI	+	+	+	+	+

NI = Not identified

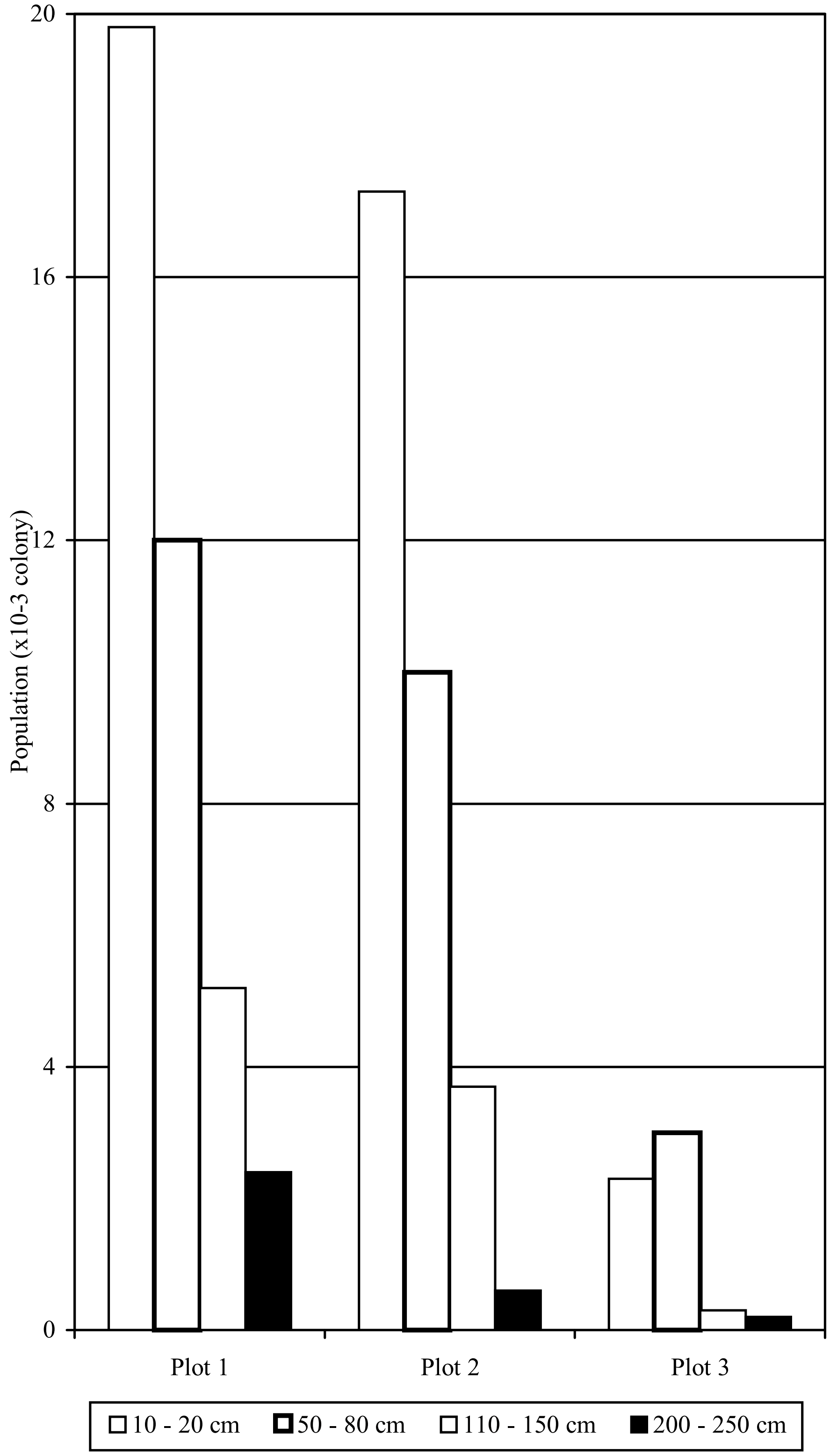

Fig. 1. Fungal population isolated from different locations and depths.

Table 2. Laccase production on lignin-guaiacol, lignin, and guaiacol media by brown-rot fungi isolated from soil and their performance for Bavendamm and Sundman test (lignin degradation)

Culture No.	Type of fungus	Colour production on			Bavendamm test	Sundman test
		Lignin guaiacol	Lignin	Guaiacol		
G4-1	*Poria* sp.	-	-	-	-	-
D6-1	*Lentinus* sp.	-	-	+	+	-
A8-1	*Serpula* sp.	+	-	+	-	-
G2-3	*Fomitopsis* sp.	-	-	+	-	-
G2-1	*Coniophora* sp.	+	-	-	-	-
D2-2	NI	-	-	-	-	+
G2-1	NI	-	-	-	-	-
G8-1	NI	-	-	-	-	+
G9-2	NI	+	-	+	+	+
D9-2	NI	-	-	-	-	-
A10-1	NI	-	-	+	-	-

NI = Not identified

Table 3. Laccase production on lignin-guaiacol, lignin and guaiacol media by other fungi isolated from soil and their performance for Bavendamm and Sundman test (lignin degradation)

Culture No.	Type of fungus	Colour production on			Bavendamm test	Sundman Test
		Lignin guaiacol	Lignin	Guaiacol		
J8-3	*Gilmaniella* sp.	+	-	+	+	+
D4-3	*Paecilomyces* sp.	-	+	-	+	+
J8-3	*Moniella* sp.	-	-	+	+	-
G8-1	NI	+	+	-	+	+
G8-2	NI	+	-	+	+	+
G10-1	NI	+	-	-	-	-
G9-2	NI	+	+	-	+	+

NI = Not identified

Although most of isolated fungi gave positive results on guaiacol, the colour intensity was varied. All the isolates of white-rot fungi gave a red colour on those three different medium respectively, in which followed by the positive reaction for Bavendamn tests. Meanwhile, few isolates of brown-rot fungi gave very light red colour and mostly gave negative reaction on Bavendamn test. It seems that brown-rot isolates required lignin substitution to induce laccase production on guaiacol, eventhough the reaction is also weak.

Lignin degradation was clearly showed only by white-rot fungi with associated to respective laccase activity and weight loss (Table 4). The lignin degradation of brown-rot isolates was less compared to that of white-rot isolates. As reported earlier, white-rot fungi is one of the most efficient lignin degraders (Leisola *et al*., 1982; Reid, 1995; Kawai *et al*., 1999).

Table 4. Decomposition of wood sawdust by different fungi

Fungi	Per cent loss		Laccase activity (U/ml)
	Total weight	Lignin	
White-rot fungi			
Amauroderma sp.	6.5	5.0	1.04
Coriolopsis sp.	12.8	12.4	2.57
Polyporus sp.	8.7	6.3	1.33
Fomes sp.	12.3	11.6	2.68
Brown-rot fungi			
Poria sp.	6.0	3.5	0.01
Lentinus sp.	5.4	1.9	-
Serpula sp.	5.8	2.4	0.001
Other fungi			
Gilmaniella sp.	2.3	0.1	0
Paecillomyces sp.	3.8	0.5	0.01
Moniella sp.	2.1	0.03	0

The results revealed good evidence on the correlation of phenoloxidase production, Bavendamn test with lignin-degrading capacity. Thus, all isolates of white-rot fungi produced colored zones followed by lignin loss and respective laccase activity. The highest lignin loss was resulted from *Coriolopsis* sp. (A9-3) and *Fomes* sp. (pAl-15). On the opposite, brown-rot isolates resulted in only little decrease in lignin with low laccase activity.

Conclusions

The study suggests that oxidation of guaiacol accompanied by Bavendamn test may provide a simple method for screening fungi with lignin-degrading capacity. It means that the isolates can oxidize phenols in agar media, they might utilize lignin.

Several fungi are induced by lignin (indulin AT), therefore any induced activity should have been evident by colorization of one or more of the media containing phenols.

White-rot fungi provided representative phenoloxidase activity whereas low phenoloxidase activity was found in brown-rot fungi. A more in-depth study of identification within this is necessary.

Tropical peat soils are a rich source of highly ligninolytic strains. They should be examined more closely.

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Microbial Population and Greenhouse Gases Formation in Tropical Peatlands under Different Land Uses

Abdul HADI[1,2] and Kazuyuki INUBUSHI[1*]
[1] Faculty of Horticulture, Chiba University, Matsudo, Chiba 271-8510, Japan
[2] Faculty of Agriculture, Lambung Mangkurat University, Banjarbaru 70714, Indonesia
* Corresponding author

Abstract

Microbial population and formation of N_2O, CH_4 and CO_2 in tropical peatlands under different land uses were studied in the laboratory. Three sites in South Kalimantan and 1 site in Hokkaido were chosen to represent different land uses. The three sites in South Kalimantan comprised of A-1 - secondary forest, A-2 - cultivated to rice since 1996 (2 year running), and A-3 - cultivated to rice during the first 3 year since 1992 and cultivated to rice-soybean in rotation since then. Site in Hokkaido (H) is a reserved area appeared as secondary forest. Soil physicochemical properties and number of microorganisms were determined soon after soil sampling. To study the effect of moisture content and land use management on the formation of N_2O, CH_4 and CO_2, soil moisture content of soil samples were adjusted to 60% moisture level or submerged. Soil samples were then transferred into 120 ml serum bottles, five bottles for each treatment, and incubated at 28°C for 60 days.

The results of experiment suggested that converting forest to agricultural fields considerably decreased the contents of organic carbon and numbers of microorganisms. At the same time, converting tropical peatlands to agriculture land enhanced the formation of N_2O. Land use change of tropical peatlands, however, did not lead to a significant increase in CH_4 emission because the formation rates were considerably low irrespective to land use management. The effect of land use change in tropical peat soil on the formation of CO_2 was also not significant.

Introduction

Peatlands are composed by soils which contain at least 30% by weight of organic matter, in the top of 40 cm and cover at least 80% of the area (FAO, 1988). Approximately 29 million ha is tropical peatlands worldwide (Takai, 1997). A large portion of this tropical peatlands exists in the Borneo Island (Driesen, 1981; Takai 1997), which belongs to three countries (i.e. Indonesia, Malaysia and Brunei).

Recently, large areas of natural peatlands have been converted for agricultural and aquacultural purposes in South Kalimantan (Indonesia) because of the intensification of agriculture due to growing population in this area (Moehansyah, 1988; MacKinnon et al., 1996). Rice crop have been grown on most peatland in South Kalimantan (about 200,000 ha) (Ismunadji and Soepardi, 1984; Radjagukguk, 1990).

Large amounts of ammonium (NH_4^+), nitrate (NO_3^-) and organic carbon accumulate when organic matter in peat soil undergoes either aerobic or anaerobic decomposition (Driesen, 1981; Ismunadji and Soepardi, 1984). This could pose a great threat to the environment by emitting various gases like nitrous oxide (N_2O), methane (CH_4) and carbon dioxide (CO_2). However, there is a lack of quantitative information regarding the emission of N_2O, CH_4 and CO_2 from natural and converted peatland (Terry *et al*., 1981, Bouwman, 1990; Agustin *et al*., 1998, Inubushi *et al*., 1998). The effect of land use change of tropical peatlands on soil microbial population is poorly understood. Since the ecosystem of the peat land is very vulnerable and readily affected by human activities (Reddy and Patrick, 1993; Tay *et al*., 1996), improper land use management could lead to increased loss of land resource and hence could enhance environmental risks. Thus a more detailed knowledge about the functioning of the ecosystem of peat soil is truly needed. The present study was therefore carried out to investigate the microbial population and formation of N_2O, CH_4 and CO_2 in tropical peatlands under different land uses.

Materials and Methods

Three sites in South Kalimantan and 1 site in Hokkaido were chosen to represent different land uses. The three sites in South Kalimantan comprised of A-1 - secondary forest, A-2 - cultivated to rice since 1996 (2 year running), and A-3 - cultivated to rice during the first 3 year since 1992 and cultivated to rice-soybean in rotation since then. Site in Hokkaido (H) is a reserved area appeared as secondary forest. Each site was surveyed following 100 × 100 m separate grids. Soil samples were taken up to a depth of 15 cm from randomly selected points during the late raining season of 1998. Each sample was a composite of points taken about 30 m apart. The moisture contents of the soil samples were 71, 63, 31 and 86 % for A-1, A-2, A-3 and H, respectively.

Contents of organic carbon, total nitrogen, water soluble organic carbon (SOC), ammonium and nitrate-N, cation exchangeable capacity (CEC), numbers of total culturable bacteria and fungi, number of cellulolitic microorganisms, and numbers of NH_4^+ oxidizers and denitrifiers were determined soon after soil sampling. To study the effect of moisture content and land use management on the formation of N_2O, CH_4 and CO_2, deionized H_2O was added to soils from rice-soybean rotation field (A-3); while other samples were dried to bring them to 60% moisture level. Soil samples were transferred into 120 ml serum bottles, five bottles for each treatment, and incubated at 28°C for 60 days. The water status of soils were maintained at the initial condition during the entire period by adding distilled water every 2 days. Bottles were only stoppered 2 days before each gas sampling, aside from this the bottles remained un-stoppered throughout the incubation. Gas sampling was carried out in triplicate at 2, 5, 13 and 46 days of incubation. The NH_4^+ and NO_3^- concentrations were measured when the formation rate of N_2O were maximum (i.e. 0, 5 and 60 days of incubation). Another set of soil samples were prepared similarly and incubated under flooded condition (i.e. 2 cm water depth) by adding deionized water.

To determine the optimum moisture level for optimum N_2O emission, soil samples from paddy field (site A-2) were first brought to 70, 80 and 100% moisture levels and submerged condition, and were then taken into 120 ml serum bottles. These soil samples were incubated at 28°C for 2 days and analyzed for N_2O emission.

The contents of organic carbon, total nitrogen, cation exchangeable capacity (CEC), and numbers of total culturable bacteria and fungi were determined with methods described by Black *et al*. (1965). Water soluble organic carbon (SOC) was determined with method described by Murase *et al*. (1996) after 1 h extraction on mechanical shaker with distilled water at 1:5 (soil:water) ratio. The concentrations of ammonium and nitrate-N were measured in KCl extract by using the nitroprusside (Anderson and Ingram, 1989) and hydrazine reduction (Hayashi *et al*., 1997) methods, respectively. Numbers of cellulolitic bacteria and fungi were determined with method described by Suyama *et al*. (1993). Numbers of ammonium oxidizer and denitrifiers were determined by methods described by Rowe *et al*. (1977) and Black *et al*. (1965), respectively. Gas samples were taken with gas-tight syringe and the concentrations of N_2O, CH_4 and CO_2 were quantified with gas chromatograph (Shimadzu 7A, Japan) equipped with electron capture (EC), flame ionization (FI) and thermal capture (TC) detectors for N_2O, CH_4 and CO_2, respectively.

Soil dry weight and volume of head space of bottles were finally measured gravimetrically.

Results and Discussion

Land use change significantly affected the contents of organic carbon and total nitrogen of tropical peat soil (Table 1). The content of organic carbon was the lowest in paddy field (site A-2), followed by rice-soybean rotation field (site B-3) and secondary forest (site A-1). This indicated that the loss of organic matter was more from paddy field as compared to secondary forest or rice-soybean rotation field. The loss of soil carbon is mainly through biomass burning that is commonly practiced during land clearing of natural tropical peatlands. Crops rotation (i.e. rice-soybean rotation) resulted in a higher soil organic carbon than rice crop alone.

Table 1. Physicochemical properties of soil used.

Site	Site code	Land use	Org C g kg^{-1}	Total N	CEC c+mol kg^{-1}
Japan					
Obihiro	H	Reservation area, secondary forest	nd	nd	nd
Indonesia					
Amuntai	A-1	Secondary forest	475.1	23.1	103.7
	A-2	Paddy field, 2 year running	225.0	21.0	120.1
	A-3	Rice-soybean rotation field, 6 year running	311.2	13.2	103.5

Total nitrogen was the lowest in rice-soybean rotation field (A-3), followed by secondary forest (site A-1) and paddy field (A-2) (Table 1). The reason for remarkable decrease in total nitrogen in rice-soybean rotation field remained unknown. The decrease in total nitrogen in paddy field may be due to the biomass burning as mentioned earlier for soil organic carbon.

Similar to soil total nitrogen, water soluble organic carbon and NH_4^+ were the lowest in rice-soybean rotation field (site A-3), followed by rice field (site A-2) and secondary forest (site A-1) (Fig. 1). However, the nitrate contents in three sites considered in this study did not differ significantly.

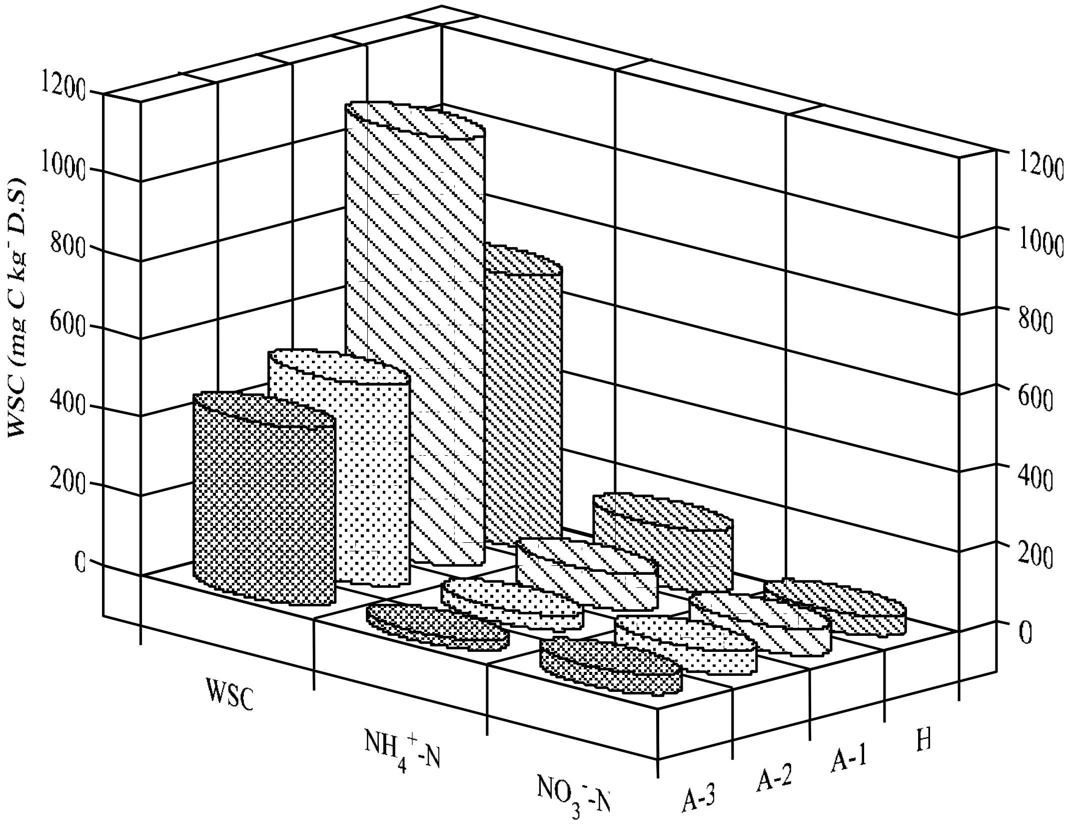

Fig. 1. Concentrations of water soluble carbon (SOC), NH_4^+ and NO_3^- in tropical peat soils as affected by land-use change.

Numbers of total culturable bacteria and fungi in rice-soybean rotation field (A-3) was about 10 times less than that in secondary forest (both in tropics, site A-1, and temperate, site H). Similarly, numbers of cellulolitic bacteria and fungi in rice soybean rotation field (site A-3) was 10 times lower than that in secondary forest (A-1). However, the number of bacteria and fungi in paddy field (site A-2) were comparable to that in secondary forests (site A-1 and site H) (Fig. 2). This indicated that land use change, for long term in particular (i.e. 6 years), had a significant impact on the number of bacteria and fungi.

Ammonium oxidizers are responsible for the conversion of NH_4^+ to NO_3^- while denitrifiers are responsible to the conversion of NO_3^- to N_2O (Paul and Clark, 1996). It was found that the numbers of NH_4^+ oxidizers and denitrifiers in paddy field (A-1) were about 50 time less than that in secondary forest (A-1), and the their numbers in rice-soybean rotation filed (site A-3) were about 10 times lower than that in paddy field (A-2) (Fig. 3). These results suggested that land use change of tropical peatlands suppressed the numbers of both NH_4^+ oxidizer and denitrifiers (Fig. 3). Fig. 3 also showed that the number of NH_4^+ oxidizers was always higher than that of denitrifiers, irrespective to land use management.

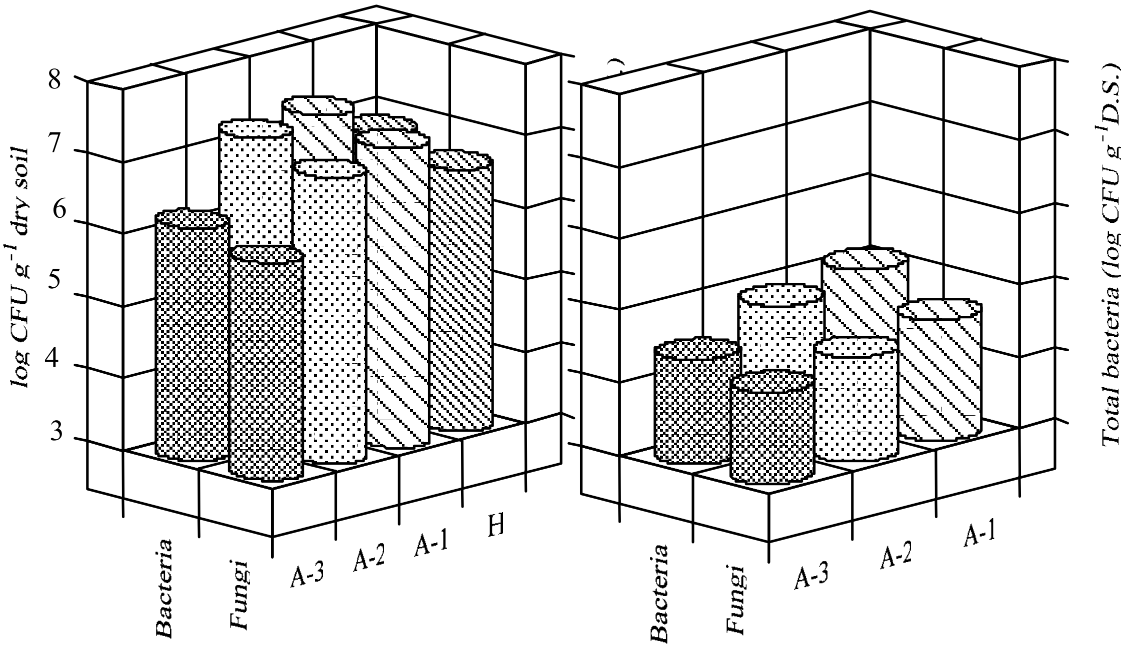

Fig. 2. Populations of total culturable bacteria, total culturable fungi (left) and cellulolitic bacteria and fungi (right) as affected by land-use change, Determination of cellulolitic neither bacteria nor fungi was done for site H.

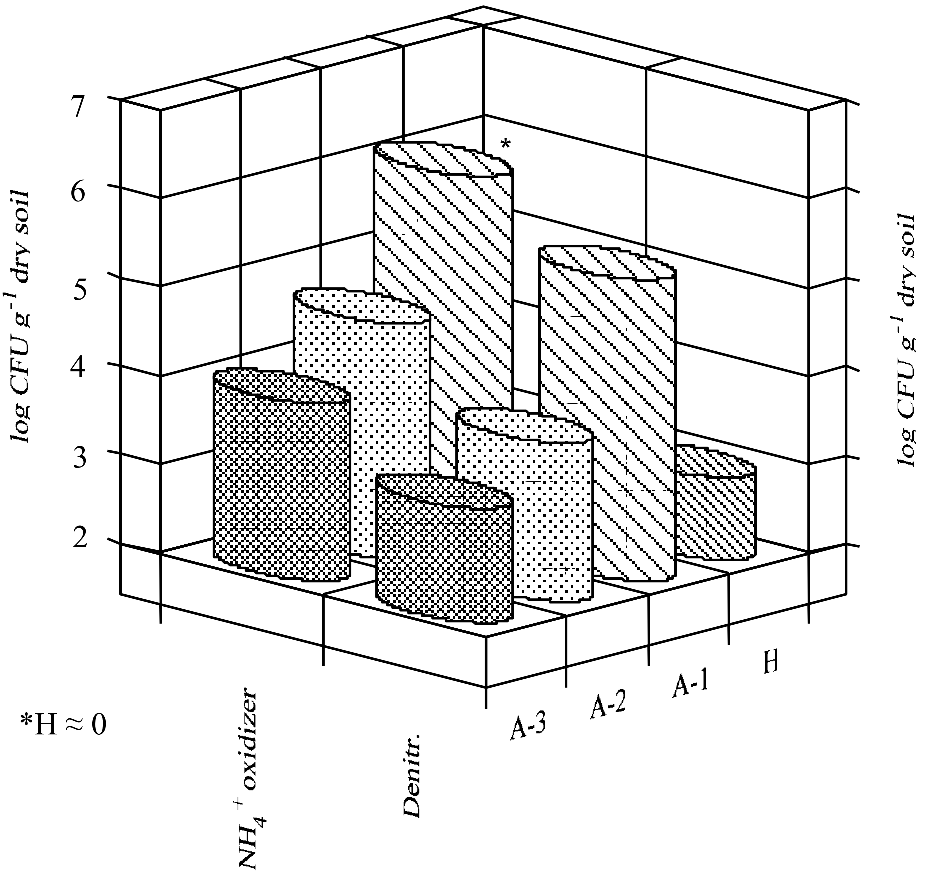

Fig. 3. Populations of NH_4^+ oxidizer and denitrifiers in peat soils as affected by land-use change.

Soil moisture content and land use management significantly affected the formation of N_2O, CH_4 and CO_2 (Fig. 4). Their effects were especially pronounced on the formation rates of N_2O and CH_4. At moisture content of 60%, paddy field formed (A-2) as much N_2O as that of secondary forest (A-1) which was higher than that of rice-soybean field (A-3).

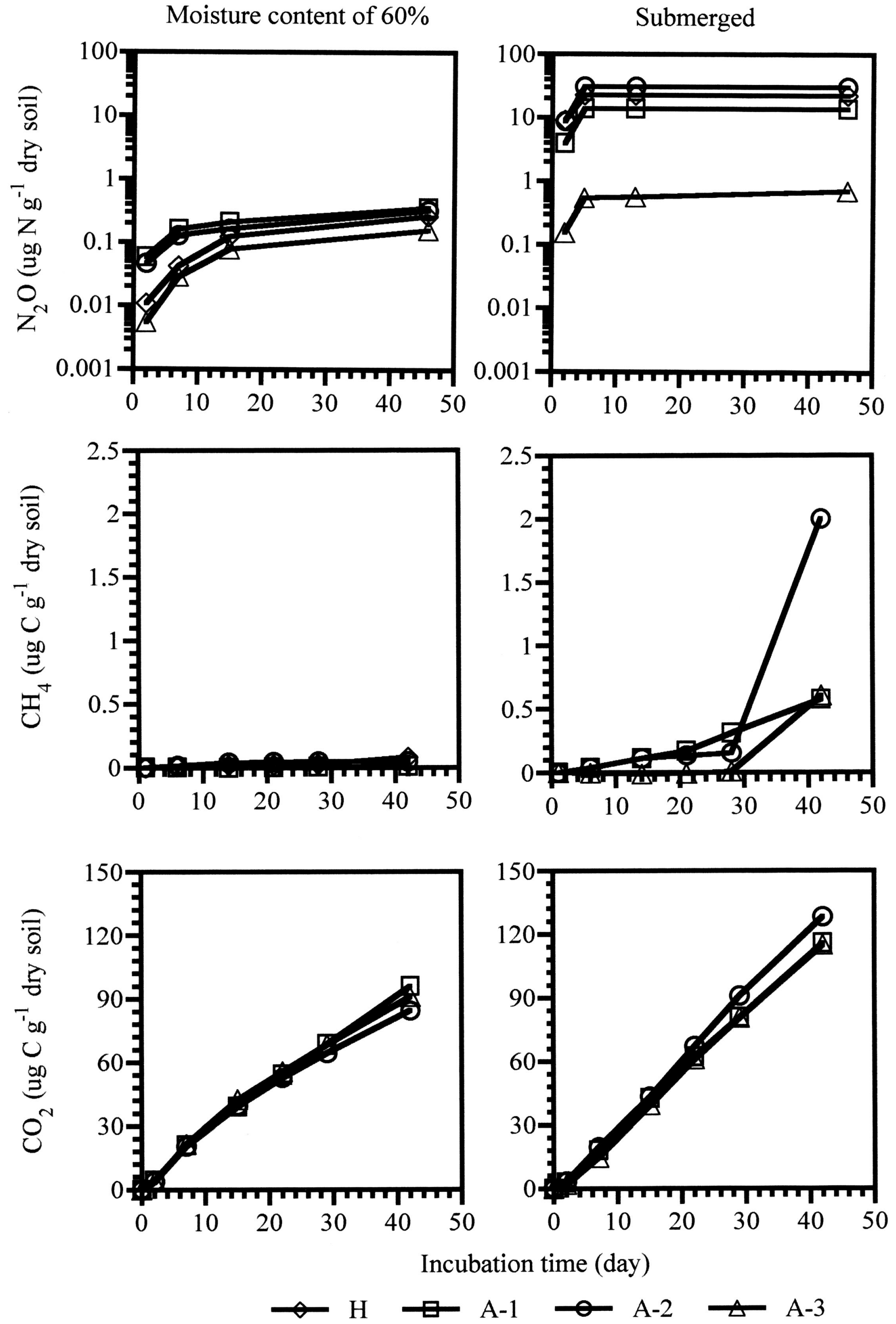

Fig. 4. Cumulative amounts of N_2O, CH_4 and CO_2 during 46 days of incubation under moisture content of 60% and submerged conditions. Site H was not analyzed for CH_4 and CO_2.

Under submerged conditions, N_2O formations were highest in paddy field (A-2), followed by secondary forest (A-1) and rice-soybean rotation field (A-3) (Fig. 4). This indicated that conversion of natural tropical peatlands to cultivated land (i.e. rice field) initially increased N_2O formation. The continued use of tropical peatlands as for rice-soybean rotation field, N_2O formation rate reduced to below natural peatlands rate. Similar result obtained from tropical grassland has been reported by Keller and Reiner (1994). Though the number of NH_4^+ oxidizer and denitrifiers were lower in paddy field (site A-2) than secondary forest (site A-1) (Fig. 3), the N_2O formation rate was higher. This indicated that the conversion of natural peatlands initially increase the activities of NH_4^+ oxidizer and denitrifiers in producing N_2O. The decrease in N_2O formation rate in rice-soybean rotation field (site A-3) probably due to the less numbers of NH_4^+ oxidizer and denitrifiers in this field (Fig. 3).

Paddy field (site A-2) formed more CH_4 than secondary forest (A-1) or rice soybean rotation field when the soil samples were submerged for more than 45 days (Fig. 4). The formation rates, however, were considerably low and even much lower than those obtained from temperate peatlands (Fecher and Hammond, 1992; Wada et al., 1998), indicating that land use change of tropical peatlands did not lead to a significant increase in CH_4 emission. Similar result has been reported by Inubushi et al. (1998).

Moisture content significantly affected the formation rate of CO_2; the CO_2 formation rate was higher in soil incubated under submerged condition that of soil incubated at moisture content of 60%, irrespective to land use management (Fig. 4). Moisture content of 60% seemed to limit the CO_2 formation. This is attributed to lower activity and proliferation of microorganism due to insufficiency of water availability (Paul and Clark, 1996). The water content of 60% is considerably high for mineral soil, but considerably low for peat soil because of low bulk density of peat soil.

During the 60 days of incubation at 60% moisture content, the concentrations of ammonium decreased with time of incubation; while nitrate changed alternatively (Table 2).

Table 2. Effect of moisture content and land use management on NH_4^+ and NO_3^- concentrations in topical peat soils taken from paddy field (site A-2).

Day	Treatment		NH_4^+ (µg g^{-1} soil)			NO_3^- (µg g^{-1} soil)		
		Site*:	A-1	A-2	A-3	A-1	A-2	A-3
0	MC 60 %		157.0	143.0	190.0	0.5	20.0	32.8
5	MC 60 %		147.0	39.0	19.0	16.1	7.2	23.3
	Submerged		8.3	152.0	189.7	0	5.3	10.0
60	MC 60 %		77.5	9.4	14.1	2.5	42.2	38.0
	Submerged		25.6	59.4	201.0	0	17.2	22.0

MC 60%: moisture content of 60%

Under submerged conditions, the concentration of NH_4^+ and NO_3^- decreased during the first 5 days of incubation and increased later on, except paddy field (site A-2) that exhibited opposite pattern to that of NH_4^+ (Table 2).

The N_2O formation in soil taken from site A-2 was strongly affected by soil water content (Fig. 5). The formation rate of N_2O was lower when the soil was incubated at water content of 70% or 80% and became higher (i.e., 30 folds) when the water content was increased to 100%. The formation rate of N_2O in soil under submerged conditions was lower than that at water content of 100%. It is more likely that at moisture content of 100%, the N_2O production was higher than its consumption, resulting in a maximum N_2O emission. Contrary, under submerged conditions, some of the produced N_2O might have reduced to N2 before reaching the head space. The presence of supernatant water might have also provided less diffusivity of soil (Keller and Reiners, 1994; Mosier and Delgado, 1997). Both processes might contribute to less emission of N_2O from submerged samples.

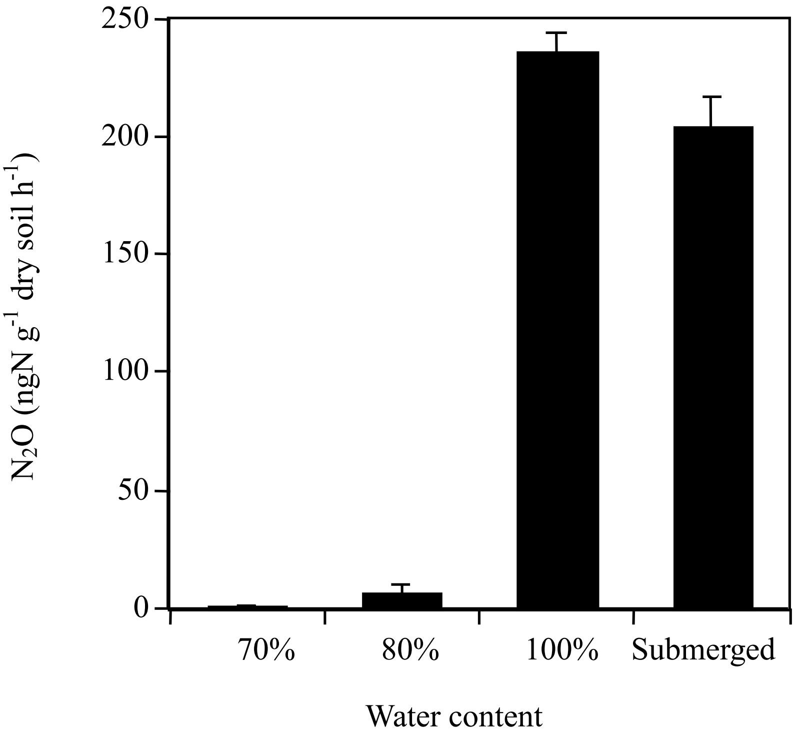

Fig. 5. Effect of moisture on the formation rates of N_2O insoil taken from site A-2 (rice field) in South Kalimantan.

Conclusions

It can be concluded that converting forest to agricultural fields considerably decreased the contents of organic carbon and numbers of microorganisms. At the same time, converting tropical peatlands to agriculture land enhanced the formation of N_2O. Land use change of tropical peatlands, however, did not lead to a significant increase in CH_4 emission because the formation rates were considerably low irrespective to land use management. The effect of land use change on the formation of CO_2 was also not significant.

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Aspect and Mechanism of Peat Fire in Tropical Peat Land: A Case Study in Central Kalimantan 1997

Aswin USUP[1], Hidenori TAKAHASHI[2] and Suwido H. LIMIN[1]
[1] Dept. Agronomy, Faculty of Agriculture, University of Palangkaraya, Central Kalimantan, Indonesia
[2] Laboratory of Geoecology, Geosince, Graduate School of Environmental Earth Science, Hokkaido University, Sapporo 060-0810, Japan.

Abstract

Forest/peat fires occur every year in tropical peatland of Southeast Asia. The areas and damages by the forest/peat fires are different with year. The impact of the peat fire on tropical peat soil depends on the local climate and response of fuel material to release of heat energy through the combustion. The fire are confined and controlled in a small area by rainfall under the normal weather condition. But it became without control under such a extremely dry weather condition as dry season in 1997.

Some aspects of peat forest fire in the peat swamp forest of Central Kalimantan were shown and analyzed in relation to microclimate, hydrological condition, peat material and vegetation.

The bulk density of peat becomes very low to 0.1-0.2 g in dry condition. The peat materials become porous and hydrophobic one in such a condition. This means the peat fire is closely related to weather, the moisture content and distribution within the peat.

The fire extension into peat layer has a different mechanism with other solid materials, because of its low density, high porosity and hydrophobic characteristics. Peat layer was partly burned made a hole on the top layer, and the hole introduced the fresh air into the deeper peat layer.

Introduction

The Central Kalimantan province was the most affected area by the 1997/1998 land and forest fires in Indonesia. The fire occurred mostly in tropical peat and peatland ecosystems in the region. This is mainly because peatlands comprised of organic matters either already decomposed or still continue to decompose which are prone to fire hazards especially during persistent drought. Peatland ecosystems in Central Kalimantan are estimated to occupy almost 2.5 million hectares with various types of vegetation. Peat swamp forests are of paramount important due to their inherent and unique characteristics that reflect their natural resource functions. Once these ecosystems are affected by extensive fires, it will not be easy and requires a very long time to recover or even lost forever.

The occurrence of tropical peatland fire depends on the availability of fuel or vegetation type, rainfall and water table level. This fire is categorised as a unique fire, due to its small ignition, spread slowly and with relatively long time period. The underground fire can reach the depth up to 100 - 150 cm, and usually very difficult to be extinguished. This paper will attempt to describe the peat fire event in Central Kalimantan in 1997.

General Forest and Land Fires in Indonesia

The forest fire in Indonesia occurred in 1984 covers 15,079.74 ha. The affected areas include South and West Sumatera, West Java and East Nusa Tenggara. In this country, the extended dry periods happened every five years that contribute to the periodicity of the occurrence of big forest and land fires. In 1985, the forest and land fires affected the area of 4,256,986 ha spreading out in 11 provinces, followed by similar fire in 1991 that occurred in 23 provinces covering 11,888,118 ha. The biggest forest and land fires occurred in 1997 covered 25 provinces with the total area reaching 26,399,200 ha. The extent of forest and land fires is depicted in Fig. 1.

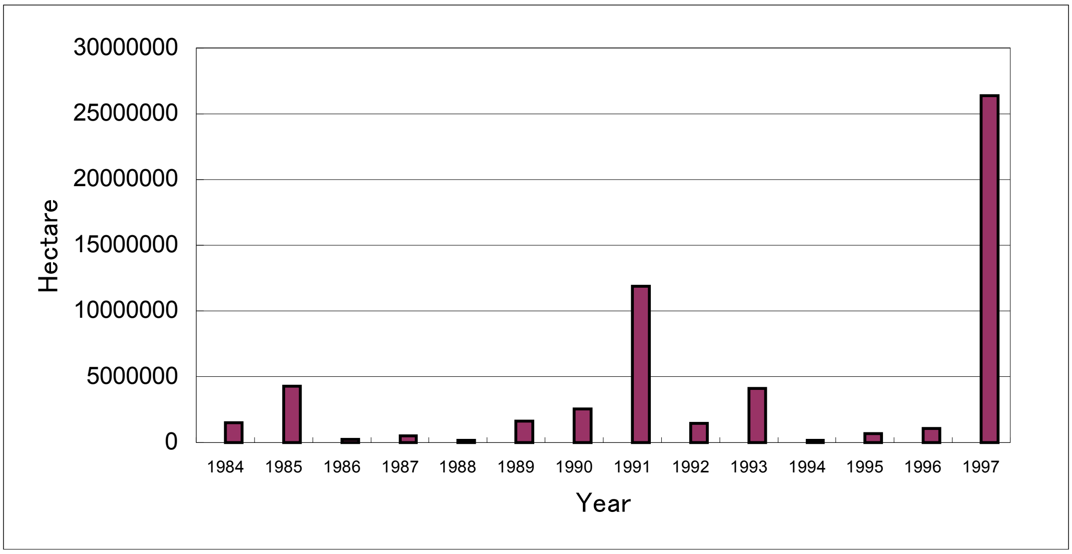

Fig. 1. Forest and land fire in Indonesia from 1984 to 1997 (Source Indonesia Ministry of Environment-UNDP 1998).

Forest and Land Fires in Central Kalimantan

In Central Kalimantan, the forest and land fires occur every year. These fires are caused by various human activities such as land clearing by farmers in opening land for ladang (traditional agriculture), rubber plantation and rattan plantation. In the traditional agricultural practice, the use of fire is a part of local people (Dayak people) life. It started since their great grandparents period. There are many benefits of using the fire for land clearing such as increasing the accessibility, controlling pest and diseases, improving soil fertility and reducing weed competition.

The events of the 1991 and 1997 forest and land fires were not controllable. The main causes of these fires were an extreme dry season, massive development of palm oil plantation, and forest clearing for transmigration settlement in Central Kalimantan.

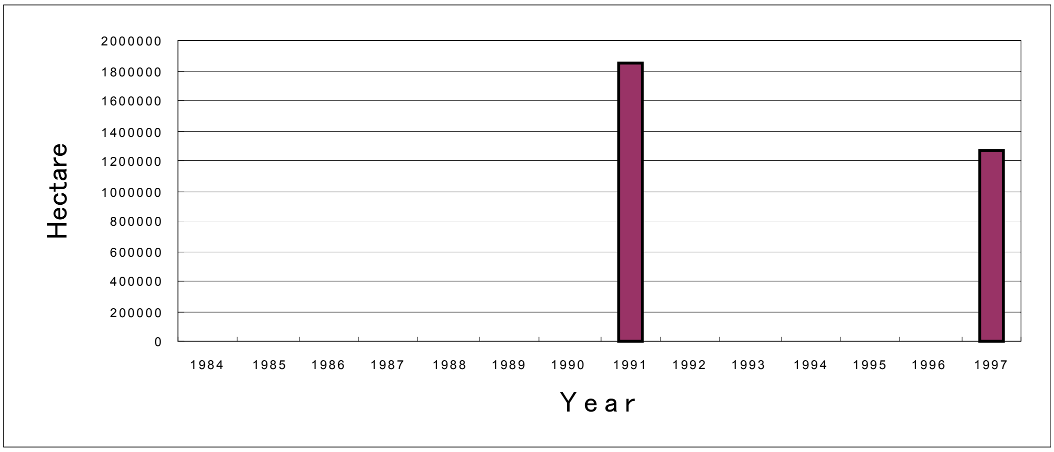

Fig. 2. Burned forest areas in Central Kalimantan from 1984 to 1997 (source: Ministry of Environment Indonesia-UNDP, 1998).

Peat Vegetation Types in Central Kalimantan

There is essentially infinite variability in fuel, types, amount, size, shape, position and arrangement of vegetation in tropical peat swamp forests. Forest floor materials such as litter and duff on the top organic soil will be ignited during fire event. These ignitions may develop into smoldering ground fires that could remain all day or even months, consume amount of duff or deep organic soil, resulting in a significant ecological and landscape change. Moisture is an important factor in discouraging ignition of ground fires. Following figures show several vegetation types in tropical peat land.

Fig. 3. Variability of peat soil vegetation in dry season as a potential fuel

Fig. 4. The small tree on peat land, that contains a kind of oil making it easy to be burned

Fig. 5. The peat land origin vegetation, usually grow in saturated water table condition and rarely burned.

Fig. 6. As a consequence of lowering ground water table, various types of grasses and alang-alang (*Imperata cylindrica*) grow on open peat, which is prone to fire.

Fig. 7. Fire in peat land that produce a dense smoke, small ignition and spread slowly.

Characteristics of Peat soil in Central Kalimantan

Approximately 10% of peat soil occur in tropical areas as a result of the decomposition of litters, leaves, branches which are common under the forest and basin areas with saturated water table (Rieley *et al*., 1997). The peat soils are potential fuel for continuos fires in drought. Its vulnerability to fire depends on its ground water level. Following figures show various soil conditions in open areas of Kalampangan, Central Kalimantan.

Fig. 8. Tropical Peat soil condition in Kalampangan Indonesia, there are many wood debris in the surface

Fig. 9. Arrangement of wood in the Tropical peat soil in Kalampangan Indonesia

Weather Condition in Central Kalimantan

Rainfall

In Central Kalimantan province, the total annual rainfall from August 1993 to July 1997 fluctuated considerably. The lowest rainfall (42 mm) occurred on May, whereas the highest (308 mm) occurred on March. The monthly rainfall varies greatly from year to year. In dry season of September 1994, for example, the total rainfall was only 0.5 mm. However, in September 1995 such value rose up to 222.5 mm (Takahashi *et al*., 1997).

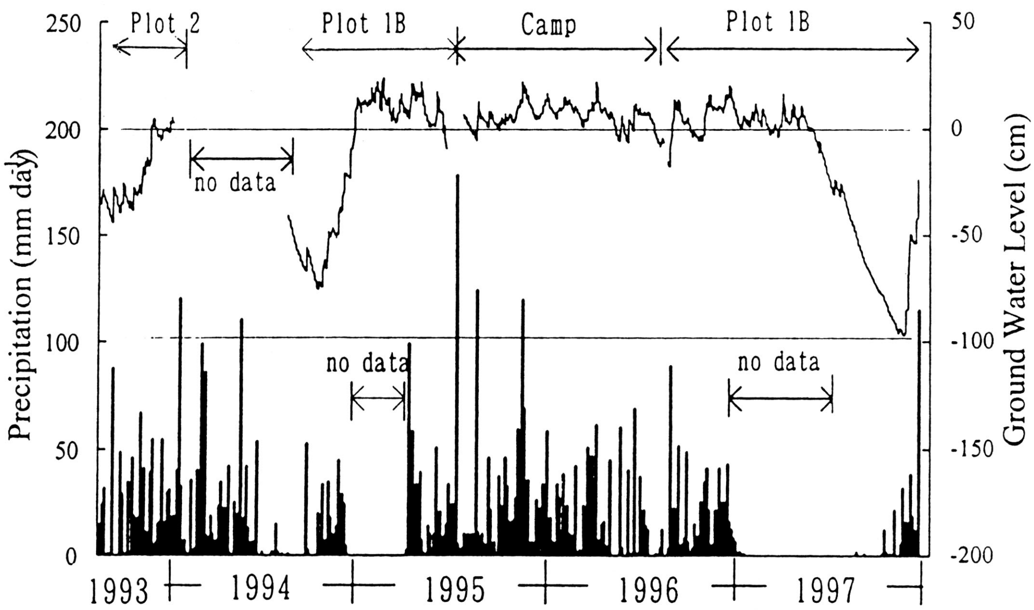

Fig. 10. Rainfall and ground water level in Sabangau Central Kalimantan from September 1993 to December 1997 (Takahashi *et al*., 1997).

Mechanism of Tropical Peat Fire

The process of burn holes development, smoldering and consumption of peat soil during peat fire is not well understood. Ignition of spot or the number of spots may be initiated by fire brand or by the passage of fire front from a surface fire, if the conditions are suitable. Once ignition occurs, the fire begins to burn downward and laterally. As smoldering progresses, a basin configuration is created. Lateral spread below the surface becomes the dominant form of spread as vertical spread reaches organic soil or smoldering moisture limits.

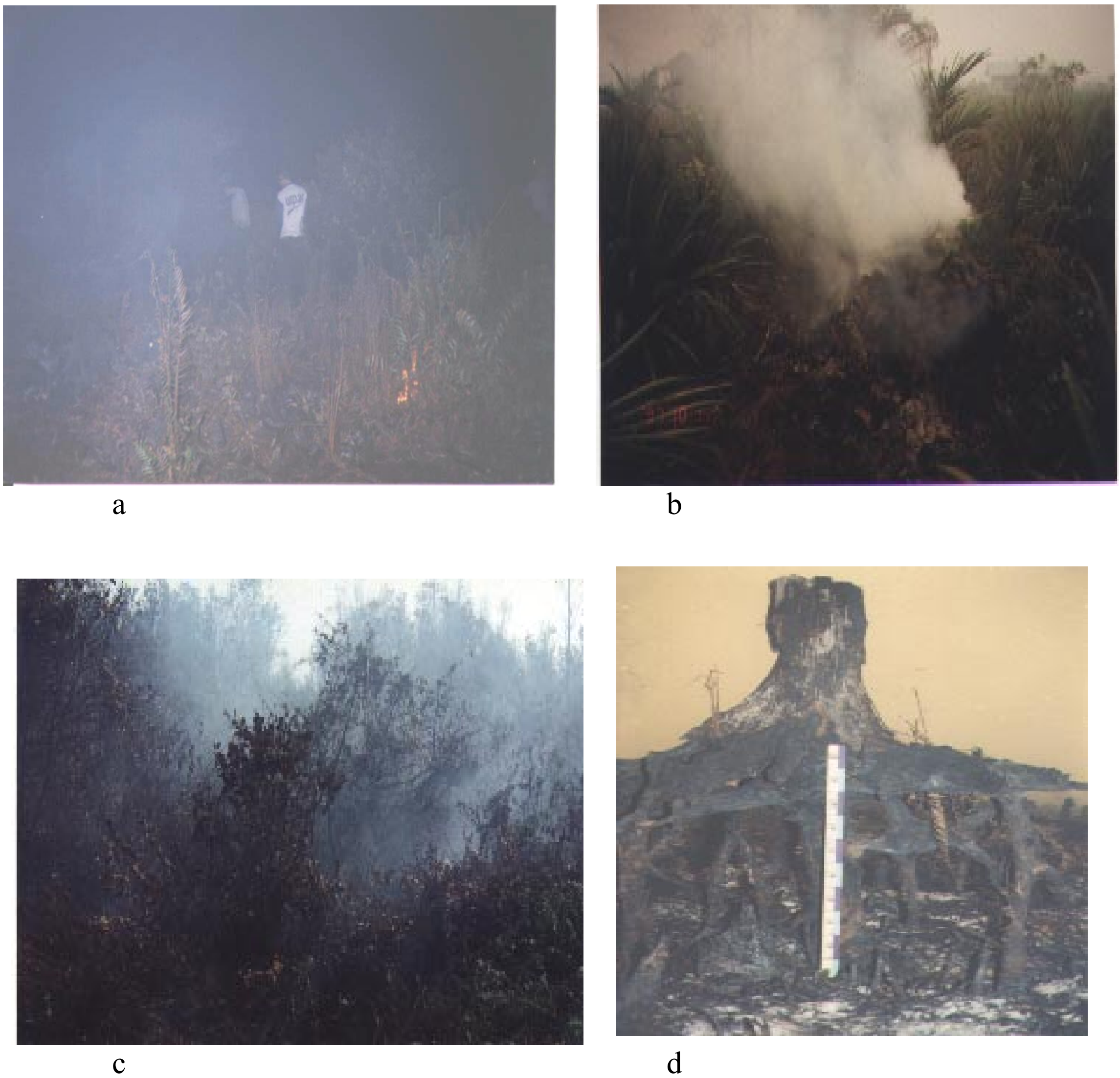

Fig. 11. The pattern of peat fires differ among fuels and vegetation types. (a) smoldering in surface fire, (b) fire produced many smoke as convection heat, (c) small trees remain fires, (d) a stump of big tree remain after burning

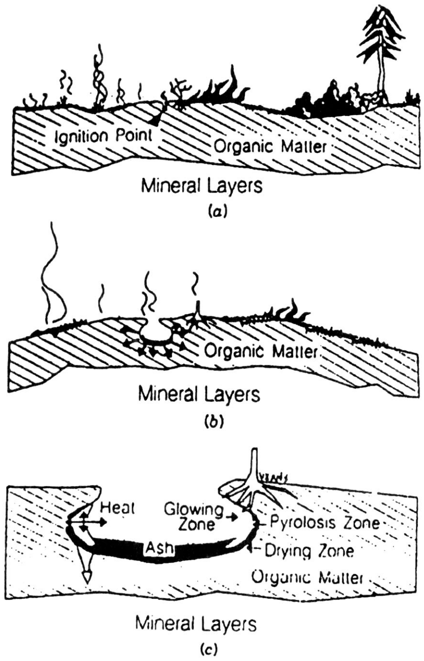

Fig. 12 Illustration developing of peat fire, (a) smoldering ignition on fire surface, (b) spread of burn hole from the initial point, (c) spread of burn to horizontal spread (Adapted from Pyne *et al.*, 1996).

a b

c d

Fig. 13. Ancient tree stumps after burning in 1997.

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Characterization and Population of Nitrogen-Fixing Bacteria from Peat Soil in Kahayan Water-Catchment, Central Kalimantan

Sri PURWANINGSIH[1], Typuk ARTININGSIH[1] and Mitsuru OSAKI[2]
[1] R&D Center for Biology, LIPI, Bogor, Indonesia
[2] Graduate School of Agriculture, Hokkaido University, Sapporo, Japan

Abstract

Nitrogen-Fixing Bacteria (NFB), which was collected from peat soil of six locations around Kahayan water-catchment in Central Kalimantan, has been successfully isolated and characterized. The peat soil samples were taken from four different depths as follows: 0-10 cm, 10-30 cm, 30-50 cm, and 50-60 cm. The growth characteristic was observed by using Yeast Extract Mannitol Agar medium (YEMA) mixed respectively with brom thymol blue and congo red as indicators.

Eighteen NFBs were isolated from twenty-one soil samples. The most number of populations was shown by the samples collected from Garung (Pulang Pisau) at 0-10 cm soil depth. Those 18 isolates grow well on YEMA medium, and mixed media of YEMA and brom thymol blue. As well, those isolates did not absorb the red color of congo red. Thirteen isolates can be grouped as fast growing, while the others belong to slow growing NFB.

Key words: Nitrogen-Fixing Bacteria, YEMA, brom thymol blue, congo red

Introduction

Central Kalimantan, one of provinces in Indonesia, is widely covered by peat ecosystem. Nowadays, the condition of peat ecosystem in Central Kalimantan is varied. Some areas are disturbed, opened by individual farmers, damaged because of extensive fire, and few areas remain natural.

Peat soil is characterized by high content of organic-matter but low in available mineral, and strongly acid in reaction. In these soil conditions, as nitrogen and phosphorus were particularly low, not only plant growth, but also microorganisms were restricted. The significant role of microorganism in mediating mineral transformation or nutrient cycle has been recognized very well. Several attempts have been focused on the use of plant growth promoting rhizobacteria (Lynch, 1983), non-symbiotic or free-living N-fixing bacteria (Rao, 1981), and phosphate-solubilizing microbes (Illmer and Schinner, 1992).

Many diazotrophic bacteria were occasionally isolated from rhizosphere soil or a variety of non-leguminous plants (Dobereiner, 1992). A newly discovered diazotrophic bacteria occurred in large numbers (up to 10^6 per gram fresh weight) in the stems of sugar cane (Gills *et al*., 1989). Application of these inoculants has broadened up for sustainability agriculture as well as possibility of increasing microbial activity within peat ecosystem. However, study on microbial application for plant growth especially in the peat ecosystem was very limited.

One of our aims in this study was to isolate and find the potential non-symbiotic N-fixing bacteria from different locations of peat ecosystem, then evaluate the growth.

Materials and Methods

Soils

Twenty one of soil samples were collected randomly from 6 locations as followed 1) Muara Bahaur, as a mangrove ecosystem; 2) Bahaur Hilir, paddy's field; 3) Pangkoh 9E, covered by grass; 4) Pangkoh 3, close to canal and mostly have been logged, 5) Pangkoh 3, logging area with alang-alang predominantly plant, and 6) Garung, Pulang Pisau, undisturbed peat forest. The samples from each location were taken from different depth soil: 0 – 10 cm, 10 – 30 cm, 30 – 50 cm, and 50 – 60 cm. Each sample was sealed in plastic bag, then stored at refrigerator.

Microbial isolation

One gram of each soil samples was mixed with 9 ml of 0.85% NaCl solution and shaken in vortex. Serial dilutions of 10^{-1} up to 10^{-5} were prepared. The suspension of 0.1 ml was plated on selected media corresponding to the intended microorganism. According to Vincent (1970), YEMA medium (Yeast Extract Mannitol Agar) was used for isolating bacteria with nitrogen-fixing capability. One litter medium consists of 0.5 g K_2HPO_4, 0.2 g $MgSO_4$, 0.1 g NaCl, 3 g $CaCO_3$, 10 g Mannitol, 3 g yeast extract, 20 g agar, and pH was adjusted to 6.8.

Growth measurement

Nitrogen-fixing bacteria from the soil samples were enumerated by spread plate analysis on solid agar media. Three plates were used for each sample. The plates were incubated at 28 ^{o}C for maximum 7 days, and developing colonies were counted everyday. The total colony was calculated as CFU (colony per gram soil) (Lynch, 1983).

For measuring the capacity of nitrogen-fixing and growth rate, the pure isolates was grown in YEMA medium containing congo red and brom thymol blue respectively, following the method of Somasegaran and Hoben (1984). The congo-red indicator was used for detecting the potentiality of the isolate for fixing nitrogen. Meanwhile, the indicator of brom thymol blue was used for measuring the growth rate of each isolate.

Results and Discussion

By using serial dilution technique, it has been found 18 isolates out of 21 soil samples. The isolation was done based on the morphology characteristics. The macroscopic characteristic of N-fixing bacteria was milky-white colony or clear colony like dropping-water with round shape and the surface is triangle-shape (Soekartadiredja, 1992).

The bacterial population from each location was varied. The bacterial population was also significantly affected by soil depth (Table 1). It is likely that the highest population of N-fixing bacteria found in natural peat forest (Garung), followed by the one from area close to canal (Pangkoh 3A).

At lower depth, the bacterial number was clearly decreased as low as 0.01×10^{5} g^{-1}, even was not found in 10–20 cm depth from the samples of Pangkoh 9E and Pangkoh 3A. These results suggest that these bacteria are associated with an aerobic habitat. The results indicate that a much higher population of bacteria exists in the soil of Garung, Pulang Pisau as a semi natural peat forest. It might be expected that plant growth in this location is better than the one of others.

Table 1. Enumeration of N-fixing bacteria from different locations and soil depths.

Location	Bacterial population (CFU g^{-1} soil, $\times 10^5$)			
	0 – 10 cm	10 – 20 cm	30 – 50 cm	50 –60 cm
Muara Bahaur – mangrove forest	38.66	43.00	16.00	5.37
Bahaur Hilir – paddy's field	1.70	0.66	0.33	0.01
Pangkoh 9E – covered by grass	10.33	-	-	-
Pangkoh 3A – close to canal	48.66	0.66	-	-
Pangkoh 3B – covered by alang-alang	5.33	0.33	0.01	0.03
Garung, Pulang Pisau – semi natural peat forest	85.00	0.40	0.21	0.01

Table 2. Growth of N-fixing bacteria on various media.

Isolate	Growth medium		
	YEMA	YEMA + BTB	YEMA + CR
1	++	++	pink
2	++	++	pink
3	+	+	light yellow
4	++	++	pink
5	++	++	pink
6	++	++	pink
7	+	+	pink
8	++	++	pink
9	++	++	pink
10	++	++	pink
11	++	++	pink
12	++	++	pink
13	++	++	pink
14	+	+	pink
15	+	+	pink
16	+	+	light yellow
17	++	++	pink
18	++	++	pink

++ : fast growing
\+ : slow growing
BTB : Brom Thymol Blue
CR : Congo Red

As shown in Table 2, thirteen isolates were classified as fast growing bacteria, which could be seen from the change color of brom thymol blue from blue to yellow color.

The potentiality of bacteria for fixing nitrogen could be detected from the color of colony occurring in YEMA medium mixed with congo red. The colony of bacteria with nitrogen-fixing capacity was not absorbed red-color of congo red. In this study, we found 16 isolates with nitrogen-fixing capability. However, these preliminary results should be followed by identification of isolated bacteria.

Conclusion

The bacterial population was significantly decreased by soil depths and varied by locations. The bacterial population in natural peat forest (Garung, Pulang Pisau) was higher than the ones other locations, which presumably to be organic-matter preference.

Eighteen numbers of bacteria were isolated from different locations of peat ecosystem, in which thirteen isolates were included to nitrogen-fixing bacteria.

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Measurement of Water Potential in Plant and Soil by the Electric Capacitance Method

Yoshio KANO
Tokyo University of Agriculture and Technology
Graduate school of Bio-Applications and Systems Engineering
2-24-16, Nakacho, Koganei, Tokyo 184-8588 Japan

Summary

It is important to know water potential in plants and in many kind of soil for increase or control of plants. As the dielectric constant of water is very large, capacitance of ceramic capacitor is proportional to content of water in its capacitor. When ceramic base of capacitor is contact with plant or soil, water potential of capacitor keep balance with that of plants or soil. The very small deference of capacitance, that is, from a few pico farads to a few femto farads, is measured by developed electric circuit. This effective circuit is consist of OP amplifier, digital IC and phase sensitive detector. Then, water potential of many kind of plants and soil are able to measure for their control. This measuring method is very useful for all kind of controlling water potential in the field of agriculture, biology and civil engineering.

Keywords: water potential, plant, moisture, soil, capacitance, dielectric constant

1. Principle

When a capacitor of ceramic base is contact with plant or soil, water potential of capacitor holds the balance that of plants or soil. Then, electric capacitance of ceramic capacitor is proportional to content of water in its capacitor as shown in Fig.1. As the dielectric constant of water is very large ($\varepsilon \approx 80$), the capacitance of ceramic capacitor is proportional to the content of water in its capacitor. If electric capacitance is measured, water potential is known.

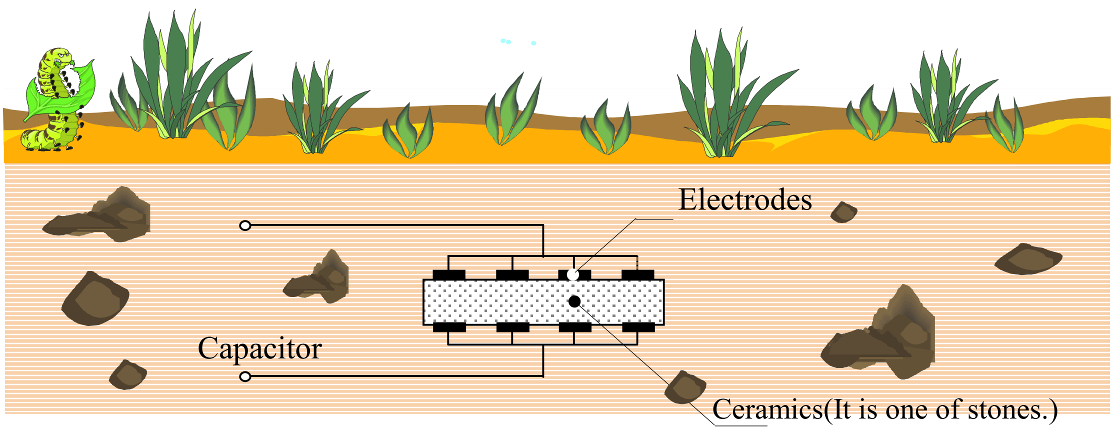
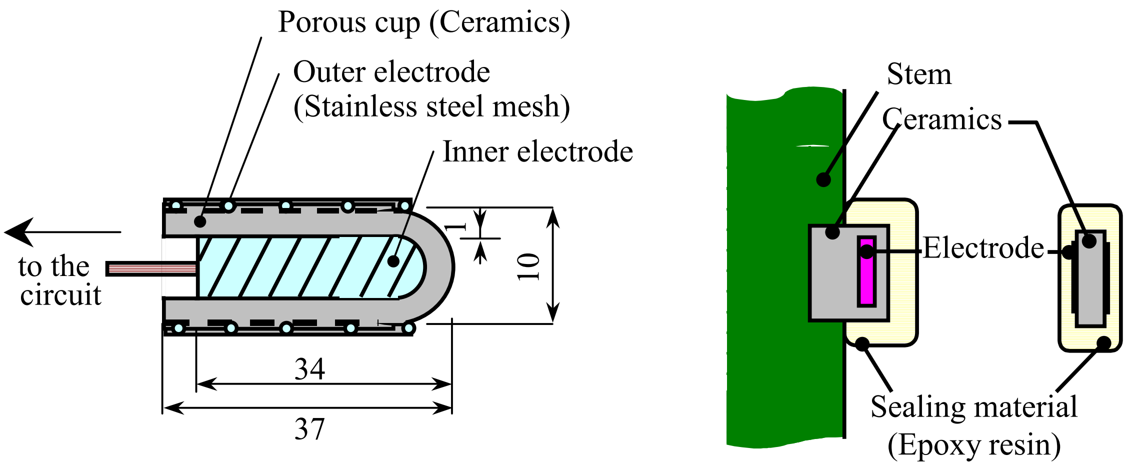


Fig.1. Water content holds the balance between the ceramic capacitor and surroundings.

2. Developed Capacitance Sensor for Measuring Water Potential

Any shape of capacitance sensor will be developed as it is desired. Two types are shown in Fig.2. The soil type that is shown in Fig.2(a) is used for measuring water potential in the soil, and the plant type that is shown in Fig. 2(b) is for water potential in the plant body.



(a) Capacitance sensor for measuring soil moisture.

(b) Capacitance sensor for measuring water potential in plant.

Fig. 2. Developed capacitance sensor for measuring water potential.

The soil type consists of a stick electrode, mesh or spiral shape electrode and ceramics. This soil type sensor is stuck into soil or is buried in soil. The capacitance between these two electrodes is proportional to Water Potential of soil.

The plant type consists of a thin ceramics (5 × 5 × 1 mm), two electrodes evaporated metal on the surface of ceramics and sealing material (epoxy resin). When a small piece of ceramics is contacted with vessel of plant, water potential of the ceramics equals to that of the plant. Water potential in a living plant is able to measure for its control using the sensor shown in Fig.2(b) and the developed electric circuit written as follows.

3. Developed Electric Circuit

The very small deference of capacitance, that is, from a few pico-Farads to a few femto-Farads, is measured by developed electric circuit. This effective circuits are consist of OP amplifier, digital IC and phase sensitive detector shown in Fig.3. Oscillator (O.S.C.) gives constant voltage to the C/V converter. If the C changes of the sensor, output voltage of C/V changes and it is detected and phase synchronous detector (P.S.D.). The output voltage is proportional to the change of capacitance of the sensor, that means water potential. A little more detail block diagram is shown in Fig.4.

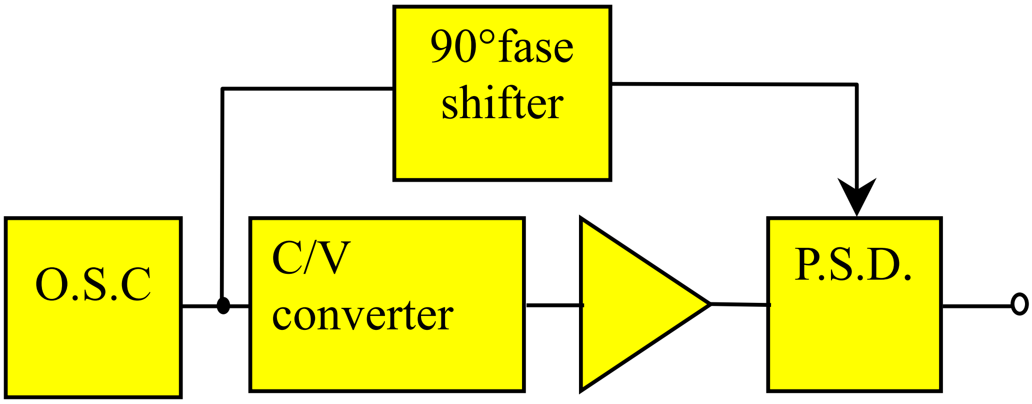


Fig.3. Fundamental block diagram of developed electric circuit of V/C converter for measuring of water potential.

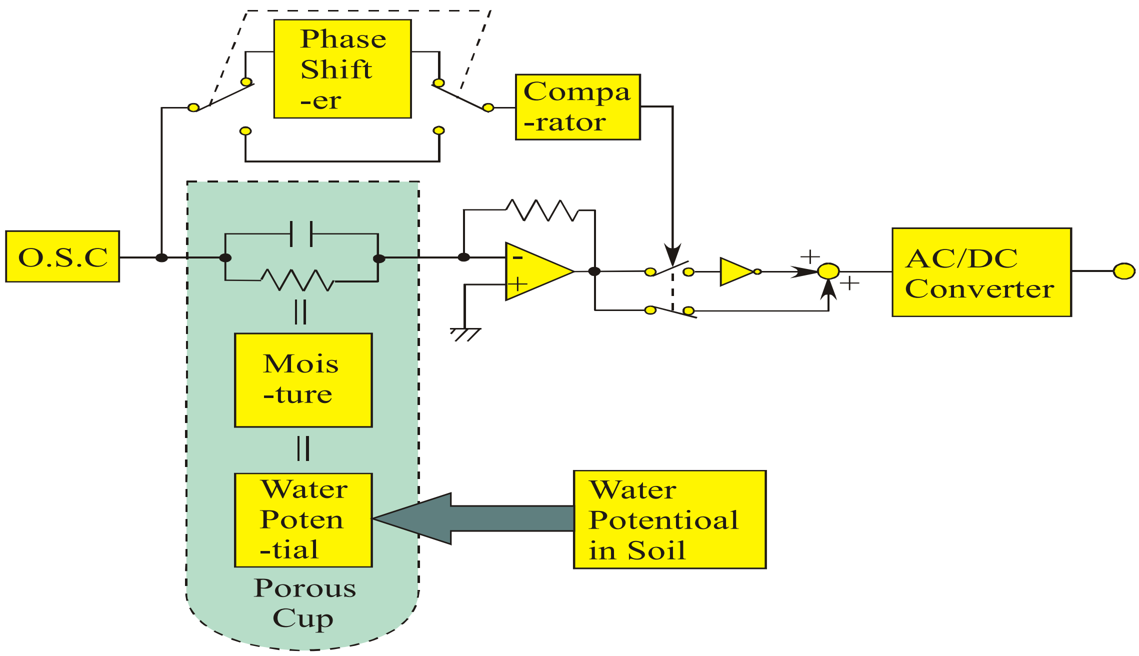


Fig. 4. Developed electric circuit of V/C converter and phase detector for measuring of water potential.

4. Characteristic of Developed Electric Circuit of V/C Converter

Actual capacitance is measured for correction. The standard capacitances which values are known, are used. It is shown in Fig.5 in which the output voltage is linear proportional to the capacitance.

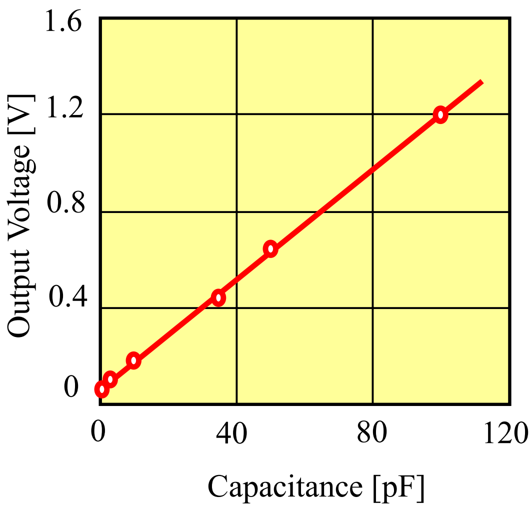


Fig. 5. Output voltage characteristic of the capacitance sensor and c/v converter

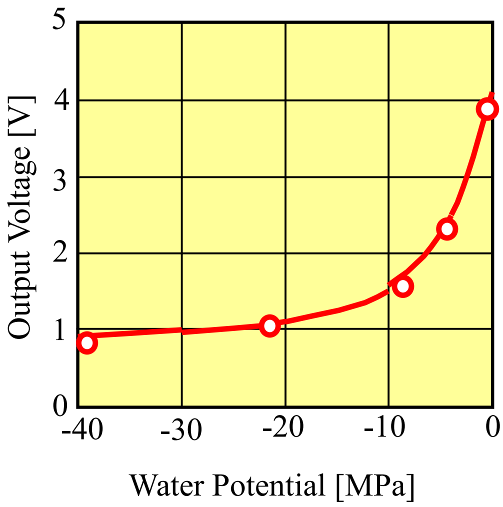


Fig.6. Output voltage characteristic of water potential of soil

5. Actual Measurement of Soil Moisture

Water potential of many kind of soil is able to measure for their control using the soil type sensor shown in the Fig.2(a). This measuring method is very useful for controlling water potential in the all kind of soil from sand to clay, because ceramics of sensor is recognized one of stone in soil. Output voltage characteristic of water potential of soil is shown in Fig.6.

6. Actual Measurement of Water Potential in Plant

Water potential in a living plant is able to measure for its control using the sensor shown in Fig.2(b). When a small piece of ceramics is contacted with vessel of plant, water potential of the ceramics equals to that of the plant. This measuring method is very useful for all kind of controlling water potential in a living plant. Actual measurement is shown in Fig.7, which show the change of water potential in a living plant poinsettia (*Euphorbia pulcherrima*) when light 5,000 lx is switched on and off. It shows the water potential decreases during the light is on because of water evaporation from leaves.

7. Conclusion

It is important to measure water potential in plants and many kind of soil for increase or control of plants.

(1) Ceramic capacitance sensor is developed.
(2) When ceramic base of capacitor is contact with plant or soil, water potential of ceramics keeps balance with that of plants or soil.
(3) Capacitance of ceramic capacitor is proportional to content of water in its capacitor.
(4) The very small deference of capacitance, that is, from a few pico farads to a few femto farads, is measured by developed electric circuit, when water potential changes.

(5) This effective circuit consists of OP amplifier, digital IC and phase sensitive detector.
(6) Water potential of many kinds of plants and soil are able to measure for their control.
(7) This measuring method is very useful for all kind of controlling water potential in the field of agriculture, biology and civil engineering.

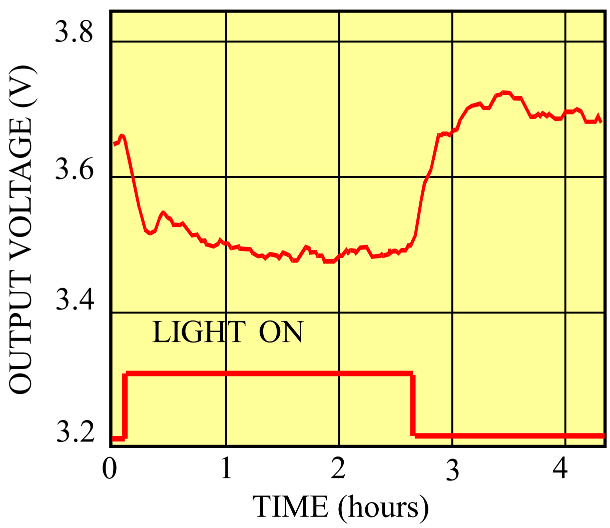


Fig. 7 The change of water potential in a living plant when a light is switched on and off.

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