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Sweet corn growth, yield, and lignocellulose decomposition on Excelzyme-treated Histosol

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Abstract. Histosol is a sub-optimal soil containing high lignocellulose resulting in its lower decomposition rate. To improve Histosol decomposition, the application of Excelzyme was used. The purposes of this study were (1) to determine the decomposition rate of lignocellulose of histosol treated with Excelzyme; and (2) to determine the best dosage of Excelzyme for the growth and yield of sweet corn. The study has been conducted at the University of Bengkulu Research Station, from July to November 2021. This experiment was designed in randomized completely block design, involving dosages of Excelzyme i.e. E0 = 0 ml plot^{-1}; E1 = 1,000 ml plot^{-1}; E2 = 1,500 ml plot^{-1}; and E3 = 2,000 ml plot^{-1}. The plot size was 2 m x 3 m, and all treatments were repeated 3 times. Results of the study showed that Excelzyme application affects the rate of histosol decomposition showed by decreasing lignin, cellulose, and hemicellulose compared with the untreated Histosol. The best dosage of Excelzyme was 2.000 ml plot^{-1} that decrease lignin, cellulose, and hemicellulose content by 32.69 %, 24,43 %, and 5.80 % in the upper 0 – 15 cm respectively compared to the untreated Histosol. While in the 15 – 30 cm depth, lignin, cellulose, and hemicellulose decrease by 25,92 %, 21.11 %, and 7.05 % respectively, compared with the untreated histosol. The application of Excelzyme of various dosages was not significantly affecting soil pH at both depths as well as sweet corn growth and yield.

1 Introduction

Histosol is one of 12 orders in Soil Taxonomy, which is the US soil taxonomic classification broadly used. Histosol is organic soil commonly called peat soil or peatland [1]. The total world peatland is comprised of about 590 million hectares (Mha) distributed in north America about 209 Mha, east Europe more than 151 Mha, the Pacific (Australia and New Zealand) is 165 Mha and tropical peat land. Tropical peatland represents about 10 to 16% of the total world peatland resources and covers around 39–66 Mha. The dominant tropical peatland is mostly distributed in Southeast Asia, mainly in Indonesia and Malaysia, covering an estimated area of more than 24 Mha [2, 3]. Indonesia covers around 36% of the world's tropical peatland, extending over Sumatra, Kalimantan, and Papua. Peatland is promising sub-optimal land since it can potentially be developed for food and vegetable crops land as

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well as for plantation estate [4]. Although converting peatland to agricultural land faces many constraints, peat conversion continuously takes place. It is triggered by the government's goal of realizing food self-sufficiency, change of agricultural land to other land used, continuously decreasing fertile land for agriculture, and increasing the human population [5, 6].

Based on its decomposition stage, peat land is grouped into three stages of development, i.e., fibric for least decomposed peat, hemic and sapric for medium, and advanced decomposed peat respectively. Peat decomposition stages significantly affect the agricultural productivity operating on peatland. Immature peat (fibric) has the most restriction for agricultural development since it has the lowest bearing capacity, lowest nutrient availability, and fast subsidence. Peat composition is dominated by complex compounds consisting of lignin, cellulose, and hemicellulose. Most decomposed peat (sapric) contains the highest lignin that is difficult to decompose, moreover in its natural condition. Water management (drainage) can improve fibric peat decomposition, but not for the hemic and sapric peat.

To remove natural vegetation and improve peat fertility for agricultural purposes, burning is widely chosen, since it is cheap and fast. However, burning cause decreasing peat properties, causing air pollution resulting in triggering global warming, and more seriously that burning peatland is illegal. Another alternative for land clearing is using herbicide, which is neither environmentally sound and potentially affects the soil properties [7, 8]

The proposed approach to solve these issues includes the utilization of extracellular enzymes. A major component of the organic substances in peatland is lignocellulose, a complex biopolymer composed of lignin, cellulose and hemicellulose derived from the wood. More advanced peat decomposition (sapric), contents higher lignin percentage in the organic substances than do hemic and fibric in peatland. The full decomposition of lignocellulosic biomass into smaller compounds depends on the type of microorganisms present in the peat soil and the enzymes they secrete [9, 10].

The purposes of this study were : (1) to determine the effect of the Excelzyme applied to selected soil chemical properties such as soil pH, lignin, cellulose, and hemicellulose; (2) to determine the effect of the Excelzyme applied on sweet corn growth and yield.

2 Materials and methods

2.1 The site, soil, and Excelzyme application

The experiment was conducted in Typic Haplosaprist during the wet season from October 2021 to January 2022 at Integrated Agricultural Research Station, the University of Bengkulu, Indonesia situated in 3045’06”S and 102017’01”E latitude with an elevation around 5 m above sea level (Fig. 1). The field was a depression area surrounded by slopping mineral land that potentially caused mineral material deposited in the peatland. Soil consists of advanced developed peat, and it was classified as Typic Haplosaprist. This zone was not manageably drained, resulting in frequent floods during the wet season. The experiment plot was established in September 2019 as a long-term experimental site for enzymatic peatland management.

Excelzyme is a consortium enzyme capable of breaking lignin, cellulose, and hemicellulose into smaller compounds. Glycoside hydrolases (GHs) are extracellular enzymes that catalyze the hydrolysis of glycosidic bonds of carbohydrate polymers. In this study. Excelzyme is an enzyme from a thermophilic organism that was used to break down the hemicellulosic polysaccharides of peat soil. A quarter dose of Excelzyme was applied to each of the experimental plots every two weeks until 4 applications, starting at the planting time. Application of the Excelzyme was started by diluting every dose of Excelzyme to 20 l with water collected from the neighboring well and pouring it into the experiment plot.

Fig. 1. Study site indicating the Peatland position is the depression between sloping mineral soils.

2.2 Laboratory and statistical analyses

Harvested plant materials were taken to the laboratory for parameter measurement and further sample handlings, such as separating shoot and root, and weighing fresh and dry biomass. Plant biomass was oven dried at 70°C for 24 h or until a constant weight was obtained. Soil samples were air dried, ground, and sieved with a 100 mesh screen and analyzed for selected soil chemical properties. Analysis of variances was done and means of treatments effects were compared using Least Significantly Different (LSD) test at a 95% level of confidence.

3 Results and discussion

Lignocellulosic peatland consisting of lignin, cellulose, and hemicellulose was affected by application of the Excelzyme either at a soil depth of 0 – 15 cm or 15 – 30 cm. Especially lignin and hemicellulose were constantly affected by Excelzyme at both soil depths as well as both times of observation. While cellulose was only affected at the observation of 12 WAT and soil depth of 15 – 30 cm. Soil pH was also only significant at 12 WAT observation and soil depth of 15 – 30 cm (Table 1). Further analysis comparing the mean of lignocellulosic utilizing LSD test at a 95% level of confidence showed a consistent result that application of the Excelzyme decreased lignin and hemicellulose content of peat materials. The treated peat showed lower lignin and hemicellulose compared with untreated peat. While the cellulose tent to unaffected by the application of the Excelzyme. It is probably because the cellulose content of sapric peat is low compared to hemicellulose and lignin content. Because of its cellulose low content, the application of the Excelzyme was not significantly affected the cellulose decomposition in this peat material (Table 2).

Observing the mean of lignocellulosic content of treated peat, indicating that application of the Excelzyme triggered lignin and hemicellulose decomposition immediately. It is indicated that mean of lignin and hemicellulose content were not significantly different between observation at 2 WAT and 12 WAT.

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Table 1. Analyses variance of lignocellulosic soil properties at a depth of 0–15cm and 15–30cm of Excelzyme - treated Histosol in Bengkulu.

Selected Variables	Calculated F 1 WAT[A]	Calculated F 12 WAT	Calculated F 1 WAT	Calculated F 12 WAT
	0 – 15 cm		15 – 30 cm	
Soil pH	3.63 ns	45,57*	0,30 ns	0,68 ns
Lignin	20,90*	20,12*	10,37*	10,17*
Cellulose	3,74 ns	5,63*	2,56 ns	3,78 ns
Hemicellulose	5,23*	15,58*	18,25*	18,84*

* Significant difference at 5% α; ns: nonsignificant at 5% α; A: Week after treatment

Table 2. Effect of the Excelzyme on lignocellulosic mean at a depth of 0–15cm and 15–30cm and at 2 and 12 WAT of Excelzyme - treated Histosol in Bengkulu.

Selected Variables	Lignocellulose content			
	0 ml plot^{-1}	1000 ml plot^{-1}	1500 ml plot^{-1}	2000 ml plot^{-1}
Observation at 2 MST with soil Depth of 0 – 15 cm				
Lignin	63,72 c	55,58 b	43,08 a	42,89 a
Cellulose	13,22	11,88	11,00	9,99
Hemicellulose	2,23 b	2,13 a	2,12 a	2,10 a
Observation at 2 MST with soil Depth of 15 – 30 cm				
Lignin	70,86 b	59,94 a	52,67 a	52,49 a
Cellulose	15,16	12,06	12,17	11,96
Hemicellulose	2,41 b	2,39 b	2,32 ab	2,24 a
Observation at 12 MST with soil Depth of 0 – 15 cm				
Lignin	58,98	51,16	38,53	38,25
Cellulose	12,00 c	10,74 b	9,84 a	8,80 a
Hemicellulose	2,08 b	1,74 a	1,77 a	1,70 a
Observation at 12 MST with soil Depth of 15 – 30 cm				
Lignin	65,46	55,11	47,56	47,20
Cellulose	13,75	10,83	10,85	10,57
Hemicellulose	2,02 c	1,85 a	1,93 b	1,84 a

Means in the same row followed with the same letter are not significantly different according to Least Significantly Different Test at 5% α.

Soil pH in peatland with high lignin content tend to be low. Soil pH in this study was generally not affected by the application of the Excelzyme except the soil pH of 0 – 15 cm soil depth at 12 WAT (Table 3). Increasing soil pH was expected when the decomposition of a lignocellulosic compound in peat was mineralized completely. The Excelzyme is only

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capable of breaking lignin, cellulose, and hemicellulose into smaller compounds, but not mineralizing them. Lamid [11] shows the schematic breakdown of lignocellulosic by the presence of Excelzyme (Fig. 2). It shows that no complete breakdown of the lignocellulosic compound was taken place.

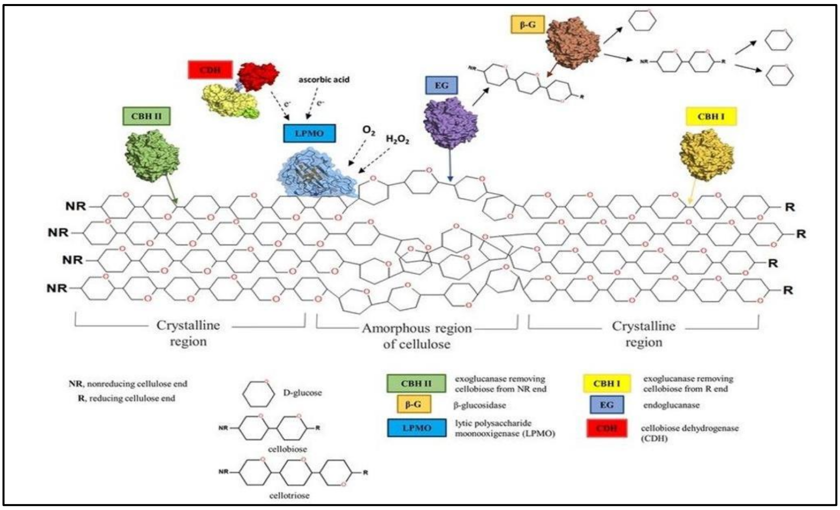

Fig. 2. Schematic breakdown of the lignocellulosic compound by the Excelzyme.

Table 3. Effect of the Excelzyme on soil pH of Excelzyme - treated Histosol in Bengkulu.

Excelzyme concentration (mL/L)	Soil pH			
	Soil Depth 0-15 cm	Soil Depth 15-30 cm	Soil Depth 0-15 cm	Soil Depth 15-30 cm
	2 WAT		12 WAT	
0	3,05	3,80	4,48 d	4,54
500	3,86	3,66	4,76 c	4,80
1000	3,22	3,71	5,02 b	4,73
2000	3,64	3,46	5,11 a	4,87

Means in the same column followed with the same letter are not significantly different according to Least Significantly Different Test at 5% α.

Except for the plant high, all parameters of sweet corn growth and yield were not significantly affected by the application of the Excelzyme (Table 4). It indicated that the decomposition of lignin, cellulose, and hemicellulose did not improve peat nutrients. It is reasonable since the breakdown of the lignocellulosic compound of peat does not cause a complete breakdown of the compound. In general, the plants were not growing well indicating that the peat was infertile, while the addition of organic-NPK fertilizers of about 750 kg ha^{-1} was not sufficient. Previous studies on peat base saturation (BS) indicate that peat soil has significantly low BS, ranging from 3.88 – 4.97 % for ombrogen peat and around 7.44 – 8.13 % of topogen (peat affected by river, sea, or tide) peat [11]. The content of Ca, Mg, K, and Na of ombrogen peat were 4.0; 2.8; 0.28, and 0.22 me 100 g^{-1} soil, respectively.

Meanwhile, peat of topogen content Ca, Mg, K, Na respectively 7.7; 5.8; 7.9, and 0.89 me 100 g^{-1}soil. Because of rigorously insufficient nutrients, the plant's performance was far from the normal condition, it makes unusual growth that plant high did not indicate the right trend (Table 4).

Table 4. Analyses variance of selected sweet corn growth and yield parameter grown in Excelzyme - treated Histosol in Bengkulu.

Selected Variables	Calculated F, 8 WAT[A]
Plant high (cm)	6,72*
Stem diameter (cm)	2,56 ^{ns}
Leaf length# (cm)	0,75 ^{ns}
Leaf wide (cm)	0,78 ^{ns}
Shoot weigh (g)	0,56 ^{ns}
Root weight (g)	1,14 ^{ns}
Shoot dray weigh #(g)	0,45 ^{ns}
Root dray weigh #(g)	1,09 ^{ns}

* Significant difference at 5% α; ^{ns}: nonsignificant at 5% [A]: Week after treatment

Table 5. Growth and yield of sweet corn grown in Excelzyme - treated Histosol in Bengkulu.

Excelzyme dose (ml plot $^{-1}$)	Plant high (cm)	Stem diameter (cm)	Leaf length (cm)	Leaf wide (cm)	Shoot fresh weight (g)	Root fresh weight (g)	Shoot dry weight (g)	Root dry weight (g)
0	61,85 a	6,34	63,05	6,19	147,95	60,35	45,11	10,74
500	58,70 a	5,00	51,95	4,87	139,25	57,50	44,47	10,45
1000	53,15 ab	5,66	50,20	5,74	148,25	57,35	53,58	14,90
2000	43,00 b	4,02	49,35	4,67	131,50	53,05	40,32	7,36

Means in the same column followed with the same letter are not significantly different according to Least Significantly Different Test at 5% α.

4 Conclusion

Results of the study showed that Excelzyme application affects the rate of histosol decomposition showed by decreasing lignin, cellulose, and hemicellulose compared with untreated histosol. The best dosage of Excelzyme was 2.000 ml plot^{-1} which is capable of decreasing lignin, cellulose, and hemicellulose content by 32.69 %, 24,43 %, and 5.80 % in the upper 0 – 15 cm respectively compared to the untreated histosol. While in the 15 – 30 cm depth, the dosage of Excelzyme 2.000 ml plot^{-1} respectively decreases lignin, cellulose, and hemicellulose by 25,92 %, 21.11 %, and 7.05 % compared with the untreated histosol. The application of Excelzyme of various dosages was not significantly affecting soil pH at both depths as well as sweet corn growth and yield.

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