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The Impact of Peatland Fires on Cellulolytic Microbial Populations in Several Landuses

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ABSTRACT

Studies on the impact of peatland fires on agricultural land, especially oil palm, and rubber, are still limited. This study aims to calculate the total population of cellulolytic bacteria and determine the activity of cellulolytic enzymes qualitatively in each microbial isolate found and to determine the level of peatland degradation after the fire. The research was conducted by survey in the field. The research location is in the long jungle village of Tambang Subdistrict, Kampar Regency. At the same time, the laboratory analysis was carried out in the Pathology, Entomology, and Microbiology Laboratory, Faculty of Agriculture and Animal Husbandry, Sultan Syarif Kasim Riau University. Determination of sample points using the purposive sampling method, which is to choose a location per the study's objectives at 4 locations. The first location is oil palm land that is not burnt, the second is burning oil palm land, the third is unburned rubber land, and the fourth is burned rubber land. Each location was repeated three times to obtain 12 sample points for observation. Furthermore, at each observation sample point, two soil depths were observed, 0-15 cm and 15-30 cm. The total population of cellulolytic bacteria in oil palm and rubber plantations that were burned and not burned with different soil depths ranged from 5.3 x 109 cfu / g soil to 14.0 x 109 cfu / g soil. The clear zone ratio (Z / K) of 8 cellulolytic bacterial isolates observed was high criteria, namely> 1.76 (100%). The highest Z / K ratio was produced by bacterial isolates originating from burnt rubber plantations at a soil depth of 0-15 cm, namely 5.25.

Keywords: *Land Fire, Peatland, Population, Cellulolytic Microbes*

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1. INTRODUCTION

Almost every year, forest and land fires (Karhutla) flare throughout Indonesia, affecting the local community, Malaysia, and Singapore. It is evidenced by the recent fires in Kota Waringin Timur and Katingan, both in Central Kalimantan. According to KLHK data, the total area of forest and land fires from January to September 2019 was 857,756 ha, with 630,451 ha of mineral land and 227,304 ha of peat. Riau Province has the most forest and land fires (Wahid, 2019).

The peatland fires that raged in Riau Province in 2019 were massive. According to data from the Ministry of Environment and Forestry, Riau Province has 75,871 acres of burned land distributed across many districts and cities. Land fires in Riau Province occur in forests and on plantations owned by businesses and communities. Oil palm plantations, rubber plantations, pineapple plantations, and other community plantations were affected by the flames. (Tanjung, 2019).

In addition to burning the flora on the ground, peat forest fires also burn the lower layers of peat (Limin, 2006). Ground fires make it more difficult to extinguish fires and burn organic stuff buried in peat and tree roots in peat forests (Adinugroho et al., 2005).

Forest fires can also have various environmental effects, including reduced soil fertility, as measured by soil characteristics. The impact of these forest fires on soil qualities in promoting plant development should be thoroughly investigated. According to Darwiati and Nurhaedah (2010), the peatland fires significantly impacted soil quality, including the physical, chemical, and biological aspects of the soil. Soil after a year of fire causes physical damage to the soil in the form of soil structure, which is caused by the loss of organic matter as a result of the burning, as well as damage at the soil microbiological population level (Hatta, 2008).

Forest fires are one of the most damaging causes of stand degradation. Large forest fires can cause significant damage in a short time. Forest fires can also harm and affect soil qualities, including physical properties, chemical properties, and soil biology (Purbowasewo, 2004).

The presence of cellulolytic bacteria is one of the soil biological features influenced by peatland fires. Cellulolytic bacteria can play a significant role in peat soil development. Its functions are not restricted to enhancing nutrient availability; it also aids litter decomposition and improves soil structure. The diverse microbial community that lives in the soil, along with numerous animals and higher plants, constitutes a living system inextricably linked to mineral materials and organic matter residues in the soil (Widawati & Sulasih, 2006).

Cellulolytic microorganisms are bacteria that can degrade cellulose. Fungi, bacteria, actinomycetes, and protozoa are all examples (Rao, 1982). Cellulose is a straight-chain polymeric carbohydrate (1,4)-ß-D-glucose in the form of fiber, clay, and is found in plant protective cell walls, particularly in stalks, stems, branches, and all woody sections of the plant. Lehninger (1982) describes plant tissue. Cellulolytic bacteria degrade cellulose to generate fiber. As Zimmermann (2004) stated, lignocellulosic natural fibers derived from wood and non-wood (bamboo, sisal, kenaf, hemp, etc.) are the most widely available raw materials on earth. The cellulose decomposition process is highly dependent on microorganisms such as cellulose-degrading bacteria.

Cellulolytic bacteria can be found in soil (Fikrinda, 2000). Litter (leaves, twigs, blossoms, and fallen fruit) is a characteristic of soil with a high concentration of cellulolytic bacteria. According to Reanida (2012), fallen leaves on the ground indicate that the cellulose content of the soil is high, implying that cellulose-degrading bacteria are quite likely to be found in the peatland environment. Bacteria, fungus, and other microbes can live in organic particles called garbage. Vegetation litter buried in the mud undergoes decomposition by various microorganisms to produce detritus and minerals for soil fertility and a source of phytoplankton life (Mahmudi, 2008).

Bacteria play a significant role in the organic matter degradation process. Bacterial activity can boost nutritional availability through carbon mineralization and nitrogen assimilation (Blum, 1988). Bacteria is one of the microbes that can degrade cellulose. Cellulolytic bacteria use cellulase enzymes to hydrolyze cellulose complexes into smaller oligosaccharides and glucose (Ibrahim, 2007). Cellulolytic means breaking down cellulose into smaller glucose units or compounds (Saratale, 2012).

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Based on the foregoing, researchers are interested in investigating the influence of peatland fires on functioning soil microbial populations in post-burning oil palm and rubber plantations. This study aims to assess the overall population of cellulolytic bacteria, the activity of cellulolytic enzymes on each microbial isolate discovered, and the degree of degradation of post-fire peatlands.

2. MATERIAL AND METHOD

Research Site and Time

This study will be conducted on peat land planted with oil palm and rubber in the Rimbo Panjang, Tambang District, Kampar Regency village. This study began with unburned and burnt rubber plantations, then moved on to burnt and non-burnt oil palm farms. The study will occur in the Pathology, Entomology, and Microbiology Laboratory, Faculty of Agriculture and

Animal Husbandry, Sultan Syarif Kasim Riau, from April to August 2020.

Tools and Materials

The tools used in the field include a peat drill, hoe, machete, polyethylene plastic, stationery, GPS, ruler, PVC pipe, styrofoam box, lux meter, thermometer, pH meter, etc. In the laboratory, the equipment used is magnetic stirrer, analytical balance, shaker, Laminar Air Flow (LAF), autoclave, petri dish, test tube, test tube rack, micropipette, Erlenmeyer, microscope, colony counter, and ice box. The medium used for cellulolytic microbial isolation with the following composition was CMC media (1 g CMC, 0.02 g MgSO4.7H2O ; 0.075 g KNO3; 0.05 g K2HPO4; 0.002 g FeSO4 7H2O ; 0.004 g CaCl2 2H2O; 0.2 g mustard extract, 1.5 gram bakto agar, and 0.1 gram glucose).

Research Method

The survey was conducted in the field, with sample points determined using the Purposive Sampling Method, which involved selecting a location based on the study objectives and doing it at four different locations. The first location is oil palm land that has not been burned, and the second location is burned oil palm land, the third location is not burned rubber land, and the fourth location is burned rubber land. Each site was repeated three times, yielding a total of 12 observation sample points. Furthermore, two soil depths were observed at each observation sample point, 0-15 cm and 15-30 cm depth. So as many as 36 units of soil samples were obtained. The research sampling unit can be seen in Table 1.

Table 1. Sample points on burned and unburned oil palm and rubber plantations

Block Sampling	Soil Depth (cm)	Repetition		
		1	2	3
Unburnt Palm Oil (STT)	0-15	STT1A	STT2A	STT3A
	15-30	STT1B	STT2B	STT3B
Burned Palm Oil (ST)	0-15	ST1A	ST2A	ST3A
	15-30	ST1B	ST2B	ST3B
Unburnt Rubber Plant (KTT)	0-15	KTT1A	KTT2A	KTT3A
	15-30	KTT1B	KTT2B	KTT3B
Burned Rubber Plant (KT)	0-15	KT1A	KT2A	KT3A
	15-30	KT1B	KT2B	KT3B

3. RESULT AND DISCUSSION

General Conditions of Research Locations

Land Conditions

Peatland fires in the Kampar district occurred in many areas. One of the burned areas is located on peat land in Dusun II, Rimba Panjang Village, Kampar Regency, with the coordinates of 00o41'10.960 north longitude 101029'84.77" east latitude. From the results of interviews with Rimba Panjang village government officials, the fire occurred on 20-30 September 2019 with a burned area of ± 40 ha, including oil palm and rubber land belonging to residents. From the research results by Taufiq and Oksana (2015), the depth of peat in the mining district is >2 m on agricultural land, while the maturity level of the peat is sapric. The research location has a flat topography with a 0-3% slope and an elevation of 10 m above sea level. According to the Schmidt-Ferguson classification, this land location has a climate type B, which is very wet.

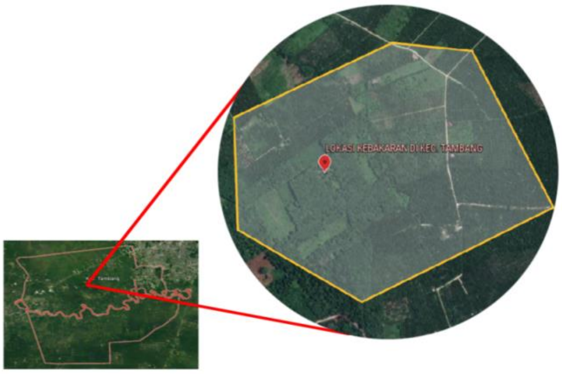

Figure 1. Map of the location of the peat land fires in Dusun II, Rimbo Panjang Village, Tambang District, Kampar Regency, Satellite Version.

The burned area has reed shrubs intermingled with ferns/Kelakay and *Gelam* trees, pioneer species on burned terrain. This is further supported by the ground surface, which still retains black charcoal on it..

Figure 2. Burnt rubber field

Figure 3. Burnt peatlands

The people living in the village of Hutan Panjang, Mining District, own the unburned oil palm property, located at coordinates 000 24'37" north longitude 1010 17'55" east latitude. The oil palm plants are estimated to be 12-15 years old, and the vegetation in the area is primarily weeds that cover the ground. The average water level in a non-burned oil palm field is 60 cm. Figure 4.4 depicts the status of a non-burned oil palm field.

Figure 4. Unburnt Palm Oil land

The plants on non-burned rubber land are believed to be 10-13 years old, and the land is owned by residents who manage it autonomously. and can be found at the coordinates 000 24'43" north longitude 1010 18'10" east latitude. Aside from the major crops, the vegetation on this property includes weeds, shrubs, and wild rubber plant seedlings. The average water level in this rubber area is 50 cm.

Figure 5. Unburnt Rubber Land

Climate Conditions

Climate is a land component that affects living things, including soil microorganisms. Climatic elements affecting soil microorganisms directly or indirectly are temperature, humidity, pH, and light intensity. Air temperature, soil temperature, soil moisture, and soil pH at the sampling location are presented in Table 4.1

Table 2. Air temperature, soil temperature, soil moisture, soil pH, and light intensity at the sampling location

Sampling Locations	Observation Parameter					
	Air Temperature (^{0}C)	Soil Temperature (^{0}C)	Soil moisture	Soil pH	Light intensity (lux)	Water Level
STT	27.33	24.00	0.70	6.03	1049.67	60
ST	32,33	29.00	0.73	6.50	7315.33	30
KTT	26.00	23.67	0.70	5.67	993.33	50
KT	33.00	28.33	0.72	6.47	6938	40

Table 4.1. shows that the air temperature of burnt areas is higher than that of non-burnt areas, which ranges from 32.33ºC - 33.00ºC. Soil temperature in this study was also higher between burnt and non-burnt land, ranging from 28.33°C to 29.00°C. Rachman's research (2020) results show that the soil temperature on burning peatlands is 27.8 °C.

Soil moisture is higher in burned land (72.00% - 73.00%) than in non-burned land (70.00%). According to Jamulya and Suratman (1993), soil moisture is water that fills some or all of the soil pores above the water table. Soil moisture can be used to predict the severity of a drought in a particular area.

The soil pH on burned peatlands is higher than on non-burned areas, ranging from 6.47 to 6.50. Hermanto and Wawan

(2017) discovered that the pH of burnt peat soil was higher (4.37) than that of unburnt peat soil (4.11). Rachman's (2020) investigation also revealed that the pH of burnt peat soil was higher (4.25) than that of unburnt peat soil (3.80).

Light intensity on burnt land showed higher light intensity than on non-burnt land, which ranged from 6938-7315 lux compared to light intensity on non-burnt land, which ranged from 993.33-1049.67 lux. The exposed land caused by the destruction of perennial plant vegetation due to fire resulted in the land getting a higher intensity of sunlight than the land covered by perennial plants. The denser vegetation and agricultural plants in a field are also the main factors affecting the high and low light intensity (Prijono & laksamana, 2016).

The groundwater level in oil palm and unburnt rubber showed a higher trend than in unburned oil palm and rubber, which was 50-60 cm compared to oil palm and burnt rubber, which was 30-40 cm. Changes in the height of the peat followed by changes in the water level result from the fire process. Increasingly in the middle of the land the height of the peat level decreases and is followed by a decrease in the water level; this is the impact of the fire process (Afriyanti, 2018).

Total Population of Cellulolytic Bacteria

Cellulolytic bacteria can produce cellulase that hydrolyzes cellulose into a simpler product, glucose (Baharuddin et al., 2010). A total of 8 bacterial isolates have been isolated from peat soils of oil palm and rubber plantations that are burned and not burned at different soil depths (Figure 6.).

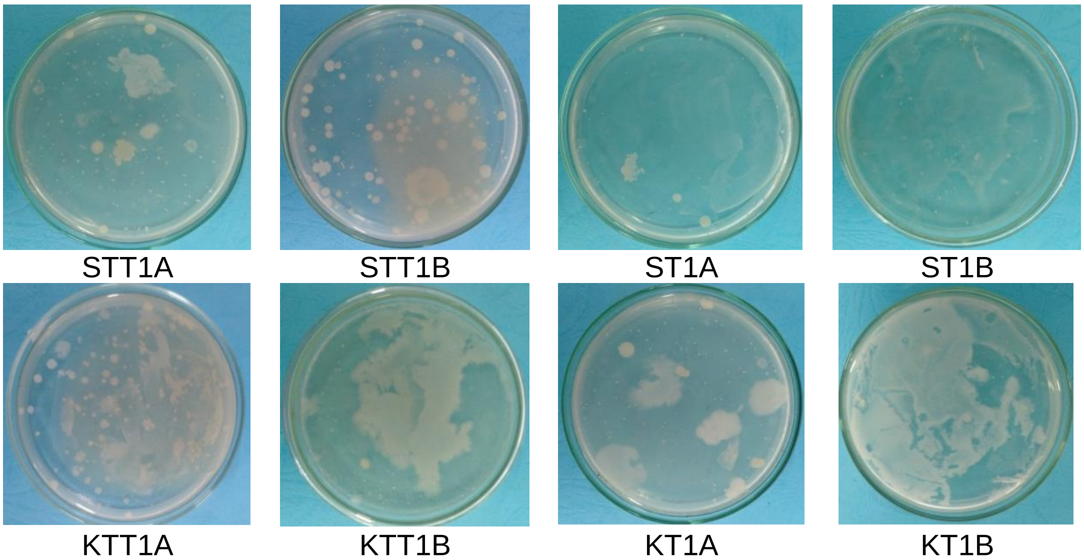

Figure 6. Bacterial isolates were isolated from burnt and non-burnt peat soils of oil palm and rubber plantations at different soil depths.

The total cellulolytic bacteria population in burned and unburned oil palm and rubber plantations with varied soil depths had different values. Figure 4.2 depicts the overall cellulolytic bacteria population in burned and unburned oil palm and rubber fields at various soil levels.

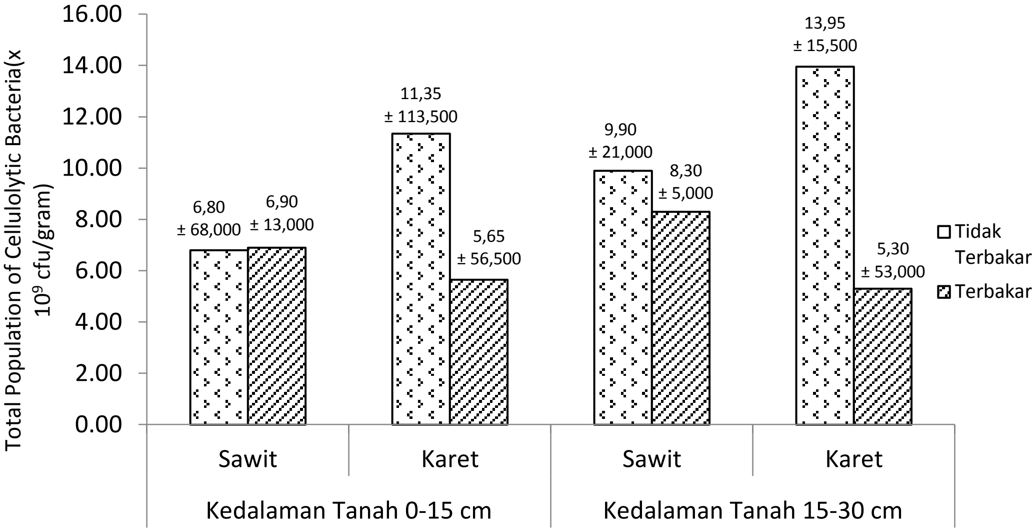

Figure 7. Total cellulolytic bacteria population (x 10^9 cfu/g) in burned and unburned oil palm and rubber plantations with different soil depths.

The total cellulolytic bacteria population in burned and unburned oil palm and rubber plantations at different soil depths ranged from 5.30 x 109 cfu/g to 13.95 x 109 cfu/g (Figure 4.2). The highest total bacterial population was found in rubber plantation locations that were not burned to a depth of 15-30 cm, namely 13.95 109 cfu/g, while the lowest total bacterial population was found in rubber plantation locations that were burned to a depth of 15-30 cm, namely 5.30 x 109 cfu. /g, meanwhile. Differences in total bacterial populations are influenced by environmental factors such as soil temperature, air temperature, soil moisture, and soil pH. Soil temperature, air temperature, soil moisture and soil pH at burnt rubber plantation locations were higher than non-burnt (table 4.1).

The air temperature in the unburned rubber area was lower (26.00ºC) than the burnt area (33.60ºC). The soil temperature in the unburnt rubber area was lower (23.67ºC) than the burnt area (28.33ºC) (Table 4.1.). This study's lower air and soil temperatures tended to have a higher total population of cellulolytic bacteria than those with higher air and soil temperatures. The results of the research by Khairiah et al. (2013) also showed that the density of cellulose-degrading bacteria at 30°C (73 x 107 cfu/g) was higher than at 33°C (0.11 x 107 cfu/g). According to Baharudin et al. (2014), the optimum temperature for bacterial growth is 25ºC - 47ºC.

The overall cellulolytic bacteria population differs depending on whether the area has been burned (Figure 4.2). The overall cellulolytic bacteria population in oil palm plantations is smaller on unburned land (6.80 x 109 cfu/g) than on burnt land (6.90 x 109 cfu/g) with a 0-15 cm soil depth. Unburned land had a greater overall population of cellulolytic bacteria (9.90 x 109 cfu/g) than burned land (8.30 x 109 cfu/g) at a 15-30 cm soil depth. This is because burned land contains less organic stuff than unburned land.

The presence of microbes is also highly influenced by the organic matter content. Carbon is a source of energy for soil microorganisms. C-organic presence can stimulate the activity of microorganisms and the decomposition process. According to Mintari et al. (2019), C-organic in peat soil with a depth of 0-20 cm which is not burnt, is higher (53.40%) than burnt land (44.71%). Likewise, on peat soil with a depth of 21-40 cm, which is not burnt, C-organic is higher (53.44%) than burnt (43.64%).

At different depths, the total population of cellulolytic bacteria yields varied values. The total population of cellulolytic bacteria was lower in oil palm fields with a depth of 0-15 cm (6.80 x 109 cfu/g to 6.90 109 cfu/g) than in oil palm fields with a depth of 15-30 cm (8.30 x 109 cfu/g to 9.90 109 cfu/g) (Figure 4.2). This contrasts with the findings of Pratiwi et al. (2018), who discovered that the overall population of bacteria in peatlands under oil palm stands is 0-20 cm greater (2.10 x 108 cfu/g) than 20-40 cm (4.50 x 105 cfu/g). In general, as soil depth increases, so does the microbial population. It differs from the bacteria in this study because it is classed as a cellulase degrader. According to Roza et al. (2013), most cellulolytic microbes live in the top layer of soil at a 0-30 cm depth and are aerobic. Environmental conditions such as temperature and pH (Table 4.2.) in this study could also support cellulase activity. According to Wahyuni et al. (2015) the air temperature range of 30.5ºC – 36.0ºC is still the optimum temperature range for cellulolytic bacteria. Furthermore, the optimum pH for cellulase activity is 6 (Marina *et al*., 2018).

Qualitative Cellulolytic Bacterial Enzyme Activity Test

Eight isolates of cellulolytic bacteria were capable of generating cellulase enzymes, with distinct zones forming surrounding the colonies (Figure 4.3.). The clear zone method degradation test is semi-quantitative since the data acquired compares the diameter of the clear zone and the diameter of the colonies generated. The formation of a clear zone is connected to the solubility of the cellulase enzyme (Roza *et al*., 2013).

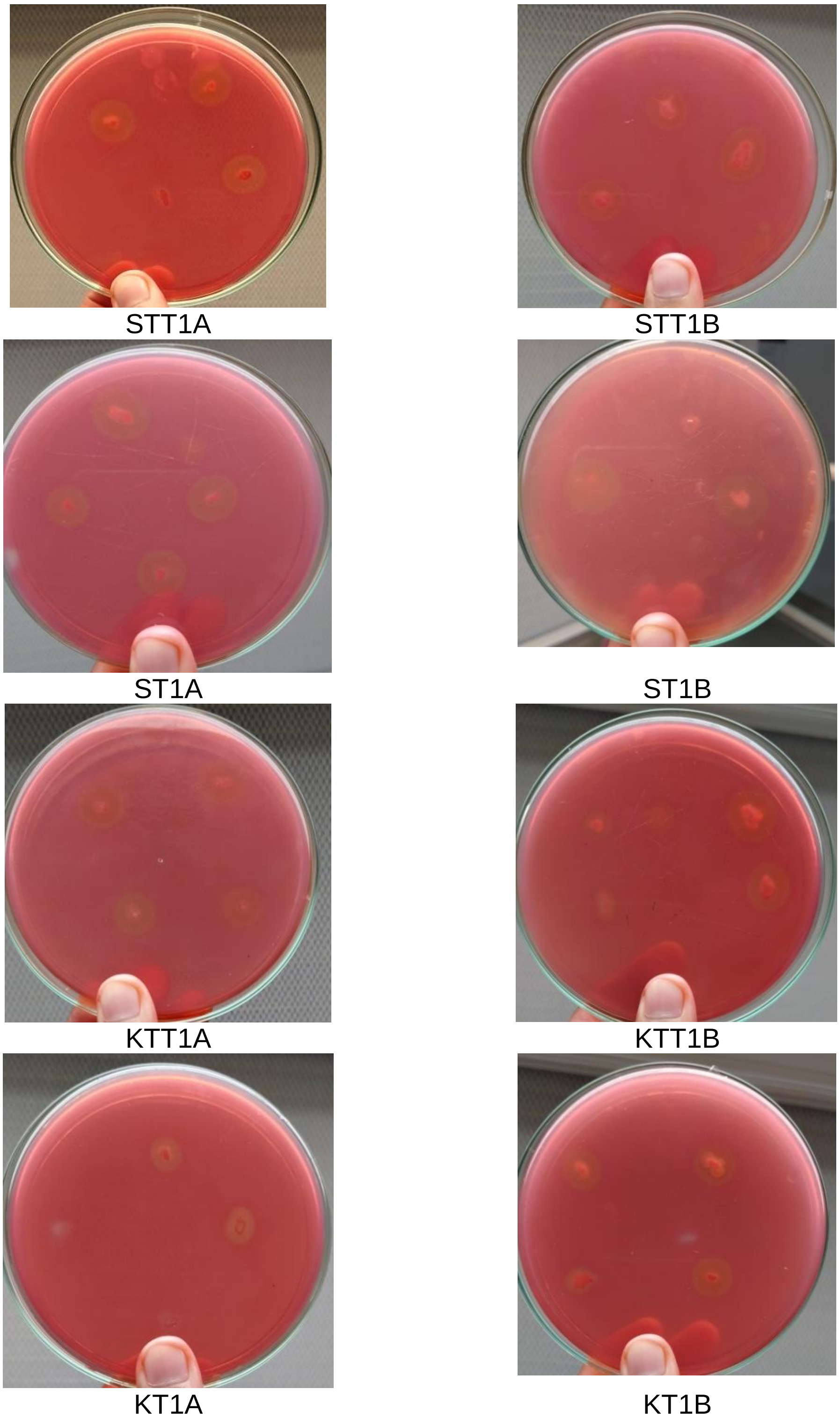

Figure 8. Qualitative Enzyme Activity Test of 8 Cellulolytic Bacteria Isolates on Medium Containing CMC

From the test results in Figure 4.3. It can be concluded that the 8 bacterial isolates isolated from burnt and unburned oil palm and rubber plantation soils at different soil depths are called cellulolytic bacteria. Bacterial isolates that were successfully isolated could utilize carbon sources derived from CMC media.

The clear zone demonstrates hydrolytic activity of the extracellular cellulase enzyme, secreted by bacterial isolates of a certain diameter (Murtiyaningsih and Hazmi, 2017). Clear zone measurements on eight cellulolytic bacteria isolates yielded varying results. The greatest clear zone measures 21 mm, while the smallest measures 11 mm (Appendix 1). In this investigation, the clear zone formed by cellulolytic bacterial isolates was smaller than that of Arifin et al. (2019), which was 30.7mm - 67.6mm.. The Z/K ratio of cellulolytic bacteria in burnt and unburned oil palm and rubber plantations with different soil depths is presented in Figure 9.

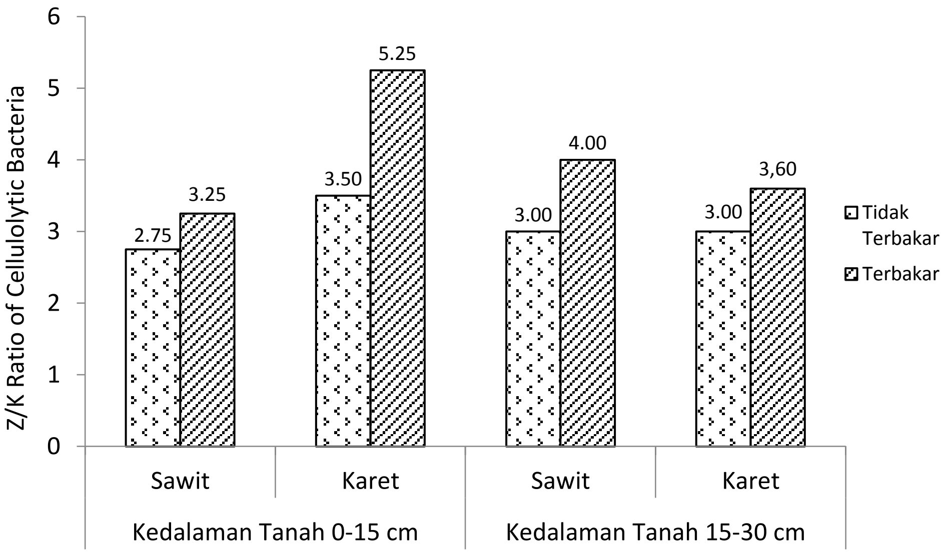

Figure 9. Z/K ratio of cellulolytic bacteria in burned and unburned oil palm and rubber plantations with different soil depths. Z/K ratio criteria: high (>1.75), medium (1.16 – 1.76) and low (<1.16).

The percolonial clear zone tests yielded a cellulolytic bacteria ratio ranging from 2.75 to 5.25. Based on the median value to the clear zone ratio (Z/K) test findings, 8 cellulolytic bacterial isolates were found to meet high standards, namely >1.76 (100%). Bacterial isolates from burnt rubber plantations produced the greatest Z/K ratio, 5.25, at 0-15 cm soil level. Meanwhile, bacterial isolates from unburned oil palm plantations at 0-15 cm soil yielded the smallest Z/K ratio, 2.75 (Figure 4.3). Semiquantitatively, these isolates are cellulolytic bacteria with comparatively strong cellulase activity in cellulose degradation compared to Hidayah et al. (2012), who reported a Z/K ratio of 37.0. The ratio of clear zones in this study was lower than that of Rohyani et al. (2014), who acquired a ratio of 13.84, and Elviana (2014), who obtained a ratio of 14).

4. CONCLUSION

At different soil levels, the total population of cellulolytic bacteria in burned and unburned oil palm and rubber plantations ranged from 5.3 x 109 cfu/g soil to 14.0 x 109 cfu/g soil. The clear zone ratio (Z/K) of the eight cellulolytic bacteria isolates studied met the high requirement of more than 1.76 (100%). Bacterial isolates from burnt rubber plantations produced the greatest Z/K ratio, 5.25, at a 0-15 cm soil level.

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