Prevention of Soil Erosion Using Microalgae in Malaysia

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Abstract. With rapid urbanization and economic development, soil erosion may occur at an alarming rate causing serious environmental problems globally including Malaysia. The current control methods such as ground covers and slope drains are expensive and not eco-friendly. Therefore, Biological Soil Crust (BSC) method can be a better alternative to prevent the soil erosion. However, most studies were focusing on in temperate and dry areas. In this work, our objectives were i) to cultivate Malaysia’s indigenous species BSC forming algae, ii) to culture the algal strain in POME medium at different concentrations, and iii) to test soil erosion in the presence of BSC. Our results have shown that algal growth had increased with the decrease of POME concentration; the algal growth was highest at the concentration of 20%. Also, the results from soil erosion tests have demonstrated that soil covered with BSC has improved soil stability by 135% compared to the soil without BSC. This suggests that BSC application is promising in preventing soil erosion. This paper is the first of its kind with the aim of providing an information on the isolation of Malaysia’s local strain in palm oil mill effluent (POME) for BSC application in the tropical climate region.

1. Introduction

Soil erosion is defined as the erosion of topsoil caused by either natural agents or induced as a result of socioeconomic development over the years. Malaysia is seeing a number of big scale physical developments including land opening activities. Uncontrolled land opening activities can lead to excessive erosion and sedimentation due to extended exposure of bare soil surface [1]. With rapid urbanization and economic development, soil erosion may occur at an alarming rate. This is one of serious environmental problems occurring globally, and Malaysia is not an exception to this issue. Given Malaysia’s tropical rainforest climate, erosion by water is the most serious form of soil degradation due to the high frequency of heavy rainfall events [2]. The current Best Management Practices to control soil erosion including but not limited to ground covers, slope drains, silt fence, blankets, and plastic covers. These methods are effective if they are properly designed and implemented. However, they tend to be expensive, less eco-friendly, and in some cases, temporary.

Therefore, it is necessary to find a better, long-term alternative to prevent the soil erosion. One of the methods is to develop artificially induced biological soil crust (BSC or biocrust) on the targeted area, which refers to the
complex communities of living organisms such as algae and fungi on the soil surface. BSC is formed at the first stage of ecological succession. BSC can help stabilize soils, protect topsoil from water and wind erosion, and keep the soil moisture. Most reports were concerned on BSC development in arid and semi-arid ecosystems. Although BSC occurs on all continents [3], studies conducted in the tropical environment are still limited. Nonetheless, Japan has been making good progress on research related to the artificial induced BSC on bare land [4].

To develop a viable research project, it is important to identify indigenous species of algae and to find culture media that are available abundantly. Previous studies had shown that palm oil mill effluent (POME) can be used to cultivate algae [5-7]. POME is wastewater generated from palm oil milling process, beneficial as a low-cost nutrient source for microalgae growth. Not that the use of POME in algal cultivation helps reduce the cultivation cost, but it also cleans the wastewater [8, 9].

This paper is the first of its kind with the aim of providing information on the cultivation of Malaysia’s local strain in POME for induced BSC application. In this work, our objectives were i) to cultivate Malaysia’s indigenous species BSC forming algae, ii) to analyze the algal growth cultivated in POME medium at different concentrations, and iii) to test soil erosion in the presence of BSC.

2. Materials and Method
This study had two set of experiments. In general, the first experiment was to cultivating the algae in POME medium at different concentrations. This experiment was an extension of our preliminary study which confirmed that algae could be cultured in POME medium (Figure 1). The second experiment was to test the growth of algae on red clay soil and whether the presence of algae on the soil could minimize soil erosion.

2.1. Cultivation of algae in POME medium of different concentrations
2.1.1. BSC sample collection.
BSC samples for this study were collected from various surfaces such as ground and concrete on the campus area of UTM, Kuala Lumpur (KL). A swab was rubbed several times on the surface where the biocrusts grow. Then, algae on the swab were dissolved in 200 mL of BG-11 medium [10]. The culture was aerated at 25°C and exposed to a continuous illumination of a white fluorescent lamp. The algal species were observed using a high definition microscope (Eclipse TS100, Nikon, Japan) equipped with a digital camera (SP-820UZ, Olympus, Japan).

![Figure 1. Algal cultured in two different media: diluted POME and BG11. Photos were taken (a) at the beginning, and (b) at the end of the experiment.](image)
2.1.2. Preparation of POME media. Wastewater samples were collected from FELDA Maokil Palm Oil Mill, Johor, Malaysia. To separate the POME, it was initially centrifuged at 5000 × g for 15 minutes. Then, the supernatant was collected, sterilized and stored in freezer at 4°C until further use. The supernatant was diluted with sterilized distilled water to the target concentrations, i.e. 20, 40, 60 and 80% (v/v). The algae were cultured with POME medium in a sterilized conical flask or a cell culture plastic flask (Thermo Fisher Scientific, Japan) (Figure 2).

![Figure 2. POME medium of different concentrations and BG-11 (control).](image)

2.1.3. Growing algae in POME and BG-11 media. A 100 µL of the cultured sample was transferred to the prepared medium. Each sample was prepared in triplicate. The room temperature was set to 25°C and exposed to fluorescent lamps. Cell counts were measured using a hemocytometer. The observations of algal growth in POME medium and BG-11 medium (served as a control) were compared to determine the optimal concentration level. Algae grown in the medium of optimal concentration was kept static for a month prior to use in soil erosion test.

2.2. Soil erosion test
2.2.1. Soil sampling. The soil sample was collected from a construction site in Cyberjaya, Selangor (Figure 3). The soil type found at this construction site was red clay.

![Figure 3. Construction site in Cyberjaya, Selangor.](image)
2.2.2. Experimental setup
Later in the laboratory (Algal Biomass Laboratory, MJIIT, UTM KL), the soil sample was soaked in distilled water and the slurry was poured off into a rectangular transparent case (15 cm × 20 cm) to form a thin layer of 5 ± 2 mm thickness (Figure 4). The soil slurry was dried in an oven at 70°C for 24 hours. After that, it was left at room temperature for a day. To cultivate, a 3-mL of algal solution was sprinkled onto the soil surface. The algae were cultured under continuous exposure of fluorescence light for two days. The soil was also watered lightly twice a day. Before conducting the soil erosion test, the rectangular case was fixed at 60° from horizontal plane. The soil samples were sprayed with water. The water volume required to cause the soil to start eroding was recorded. This test was done four times, and the average of water volume in both cases (with and without algae) were compared.

![Figure 4. The experimental setup for soil erosion test.](image)

3. Results and discussion
3.1. Effect of POME concentrations on algal growth
Figure 5 shows the cell counts of algae cultivated in POME medium diluted in the range of 20%–80%. The highest cell count was observed at the concentration of 20%, followed by 40%, 60%, and 80%. In 20% POME, algae exhibited the fastest growth rate without lag phase. Contrastingly, algal growth was slowest in 80% POME with a lag phase of 2 days. Lag phases were also observed at the concentration of 40% and 60%.

![Figure 5. Algal cell counts at different POME concentrations.](image)
On day 4, algal growth at the 20% concentration was found to have reached a stationary phase, while at the concentrations of 40% and 60%, the algal growth continued to grow. We also found that after 4 days, there were fungi and mold growing in POME medium of 80% concentration, causing the algae in the medium to die (data not shown). Our results showed that when the concentration of POME was low, the lag phase was short, and the number of cells increased faster. It can also be concluded that 20% was the optimal concentration of POME medium to grow the algae. Figure 6 shows the microscopic image of the algae used in this study.

![Microscopic image of the BSC forming algae.](image)

**Figure 6.** Microscopic image of the BSC forming algae.

### 3.2. Effect of biocrust on soil erosion

In the second experiment, we studied how the presence of BSC would affect the soil erosion. After two days of cultivation, algae were seen to grow on the soil surface (Figure 7).

![A layer of soil with and without biocrust for soil erosion test.](image)

**Figure 7.** A layer of soil with and without biocrust for soil erosion test.

Based on our results, only 43.5 mL water was required to cause the soil without BSC to start eroding compared to a total of 102.5 mL water required for the soil with BSC (Figure 8). In other words, soil stability was found to
be better by 135% with the presence of BSC. This finding suggests that BSC has reduced the erodibility of the soil by protecting the soil surface from water erosion.

Figure 8. The total volume of water to cause the soil to start running off. Error bars showing the standard deviation of four trials.

4. Conclusions
In this study, we have successfully identified the native microalgae from Malaysia that have been shown to have potential applications in soil erosion prevention. It was confirmed that the microalgae can be cultured in diluted POME medium with a concentration of up to 80%. The growth of microalgae was higher with the lower concentration; 20% POME was found to be optimal for the growth. Results from soil erosion test have demonstrated that with the presence of BSC, the soil was more resistant to water erosion by 135% compared to that without BSC, indicating that the BSC has improved soil stability. Our findings provide the basis for future BSC studies for soil erosion prevention using Malaysia’s local strain with the use of an abundant source of nutrients such as POME.

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