Aqueous Synthetic Polymer Spraying Application for Mulching of Surface Soil for Revegetation of Critically Degraded Ex-Borrow Pit Area

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Abstract. Very low soil fertility status due to borrow pit exploitation was exposed at lower soil horizon layers. Soil among the sites was classified as critical soil type. The soil layer was at C-horizon, so that was classified as not "soil" in the agricultural term, but it was more grouped as still unweathered parent mater for processing in the soil formation. Suffering on surface vegetation biodiversity was found and revegetation action was an alternative method to restore the degraded soil. Legume cover crops were selected for ameliorating pioneer plants to improve soil and vegetation biodiversity step by step towards the effective regreening of environmental health and safety. An aqueous synthetic polymer was applied to spray the soil surface after planting the legume cover crops, whereas, after the water evaporation of the solution, a degradable thin film at the soil surface was left as a mulch for controlling the water evaporation from the soil surface for a long time for a few months. The mulch kept the soil moisture higher for the growth of the legume cover crops. Field application was succeeded in 2010-2011 at an ex-borrow pit area in Jambi. Additional topsoil, fertilizer, compost, and lime were mixed as supporting growth media. Mucuna bracteata was planted before the application of the aqueous synthetic polymers spraying. Aqueous synthetic polymer spraying application for mulching of surface soil was able to reclaim the critically degraded ex-borrow pit area for the start step, whereas the vegetation covering rate of the site increased from initially less than 1% to more than 90% after 10 months application.

1. Introduction

Top soil cut and fill for infrastructure project activities of an oil and gas company or other projects in the energy and mining sectors area unavoidable. Soil degradation is a result of the site due to soil erosion in tropical humid climate regions. After cutting of top soil from a borrow pit area for filling of a project at other sites, the reclamation of this area should be conducted. Very low soil fertility status due to borrow pit exploitation was exposed at lower soil horizon layers. Soil among the sites was classified as critical soil type. The remained soil layer was positioned at C-horizon, so that was classified as not "soil" in the agricultural term, but it was more grouped as still unweathered parent mater for processing in the soil formation building. Suffering on surface vegetation biodiversity was found and revegetation action was an alternative method to restore the degraded soil.

Ex-borrow pit area to be taken in this research and observation was so far in such condition, that the covering rate by vegetation previously was less than 2%. Massive gully erosion at his area.
occurred at a continually increasing rate and became unstoppable, whereas its dimension is greater and greater during the time. A further controlling for the increase of the covering rate at least at 80% covering rate is required urgently, so that its development of massive gully erosion can be reduced and finally stopped to conserve the environment. Oil palm had been installed at the site previously at the soil C-horizon so that it could not develop properly due to lack of soil physical, chemical, and biological fertility [1][2]. An unsuitable oil palm plantation and its understory vegetation grew at such environmental circumstances. It was too far to judge, that the results of a previous conservation project to maintain ecological landscape were successful.

However, it was considerably still possible to reclaim the ex-borrow pit with a proper re-vegetation technology. The re-vegetation purpose must meet the conserving targets of long-term environmental status, i.e. natural biodiversity, soil and water conservation, social and culture acceptability as well as governmental regulations aspects. Soil evaporation reduces water availability. A newly planted vegetation is more sensitive to undergo water stress. On the other side, water runoff due to lower infiltration into the soil [3] could sweep the new planting seeds or seedling and applied fertilizer as well. The spraying with aqueous synthetic polymer at the soil surface would cover the planting area from the critical evaporation of young plants and the attack of runoff water. An aqueous synthetic polymer can be applied after planting the legume cover crops, whereas, after the water evaporation of the solution, a degradable thin film at the soil surface was left as mulch for controlling the water evaporation from the soil surface for a long time for a few months. Soil mulching or covering with the thin layer plastic or latex will reduce water evaporation, will maintain the soil moisture and has a function as a shield to protect the new planting seeds or seedlings from possible runoff water strike [4]. The use of LCC for soil covers will improve soil physical, chemical and biological fertility and promote further development of biological diversity [5][6].

The purpose of the experiment was to identify the capability of aqueous synthetic polymer spraying application for mulching of surface soil for revegetation of ex-borrow pit area with legume cover crop (LCC) to conserve the area and to promote further biodiversity development. The aspect of improving soil fertility especially on top soil conditions and naturalize the site with the revegetation technology was covered in the purposeso that the growing plants covering rate at the soil surface area reached at least 80% after ten months of vegetation growing time.

2. Methodology

The soil reclamation was conducted in ex-borrow pit area of in Village of Pematang Rahim, Kecamatan Mendahara Ulu, Kabupaten Tanjung Jabung Timur, Jambi Province. The total of the designed area is about 2.0 ha at the coordinate 335150 –335500 Easting and 9862200-9862500 Northing with reference base on WGS-84. The installment of seedbeds, application of growing media and planting of LCC seeds were completed in January 2010. The field activities of soil reclamation were completed at the first stage of soil reclamation after the soil covering rate reached a value of 80%.

Soil sampling for physical and chemical analysis was conducted for three types of C-Horizon, for 3 preliminary color and layer characteristics, i.e. brownish for upper C-horizon, reddish for middle C-horizon and white pale color for deeper C-horizon. Seedbed in dimension of 30 cm length, 15 cm width, and 15 cm depth was prepared for growing media and LCC-seeds planting. Seedbeds were prepared in the row of oil palm trees in the area, with the distance of every 2.25 m. The population of oil palm is 143 plants/ha in an equilateral triangle spacing system at a distance of 9m among the oil palm trees. There were 12 seedbed holes per the equilateral area of the spacing system. Total installed seedbeds in the 2 ha ex-borrow pit area amounted to about 6838 seedbeds.

Synthetic polymer application treatment consisted of synthetic polymer emulsion application and without polymer emulsion application as the control treatment. Each polymer treatment was applied at the three soil types i.e. brownish, reddish and white pale soils. There were 54 observation seedbed samples, which were positioned at 9 diverse positions as replication. Each seedbed and the growth of
LCC at every categorized soil type in combination with synthetic polymer emulsion application treatment were taken for the observation sample.

Additional ameliorating agents consisting of compost, manure, dolomite lime were applied for the improvement of soil growing media. The additional media composition comprised of compost: manure: dolomite = 10: 2: 1. Systemic insecticide Furadan 3G and fungicide Dithane M45 were applied at a rate of 2 kg ha⁻¹. The dolomite is applied for soil liming purpose to raise soil pH, due to the high acidity of red yellowish podzolic soil at the research site.

LCC species for planting was *Mucuna bracteata* DC. The type was expected to be capable to cover the degraded soil faster, to reclaim it and to bring back soil fertility after a few years. Before planting LCC seeds were soaked in water for two days. Pre-emergence fungicide Dithane M45, as well as systemic insecticide Furadan 3G, was applied. About 20% of LCC seeds emerged as LCC seedlings. The seedlings and the seeds were incorporated in the mixing growing media and installed in the prepared seedbeds.

A synthetic polymer as a dispersion agent of an immiscible liquid in water used was a synthetic polymer with trademark Soil Sement®. It was diluted in water with a concentration ratio of 1:20. To reduce the erosion and to prevent the seeds/seedlings discharge due to runoff or rainwater splash, the aqueous agent was sprayed over the seedbed in the amount of 10 cc per seedbed. Fertilizing, watering, replacement of unsuccessful growing plants, and pest control with legal pesticide agents were accomplished during the growing period.

3. Results and discussion

3.1. Degraded soil characteristics

The soil fertility at the ex-borrow pt area, in general performance, was classified as very low, with very low in soil humus content and organic matter content as well as its nitrogen availability. The soil fertility status contributed to the reasonable results about the growing status of vegetation [7]. The exact figure of soil fertility status for soil chemical properties is presented in table 1 and for soil physical properties in table 2.

The major criteria for soil fertility in humus status and nitrogen content in the soil are extremely under the minimum standard for soil fertility standard quality [8]. This degraded soil was observed at the soil position at the three-color types of the C-horizon layer. The 3 types of soil were categorized as very acidic soil, with pH value pH 4.3 in white pale soil, pH 3.9 in reddish soil and pH 4.4 in brownish soil. Soil C-Organics classified as very low, 0.06% in white pale and reddish soil, and 0.28 in brownish soil%. Total N-content was also classified as very low in a concentration value of 0.02 % N and 0.04 % N respectively. Cation exchange capacity (CEC) value and the content of Ca, Mg and K were also very low. CEC or Cation Exchange Capacity as an indicator of the availability of nutrient which can be absorbed by the plant through roots was extremely low. Low pH and low CEC inhibits plant growth and development [1][7].
Table 1. Status of soil chemical fertility

| No. | Parameter | Methods | Unit | Soil position at the field | Justification [B] |
|-----|-----------|---------|------|-------------------------|------------------|
|     |           |         |      | Lower (reddish) | Middle (white pale) | Upper (brownish) |
| 1   | *pH       | SNI 03-6787-2002 |          | 4.3 | 3.9 | 4.4 | very low |
|     | H2O       |          | cmol/kg | 0.13 | 0.11 | 0.62 | very low |
|     | CaCl2     |          | cmol/kg | 0.04 | 0.01 | 0.06 | very low |
| 2   | *C Org    | SNI 13-4720-1998 (Walkey & Black) | % | 0.06 | 0.06 | 0.28 | very low |
|     | *N Total  | SNI 13-4721-1998 (Kjeldahl) | % | 0.03 | 0.02 | 0.04 | very low |
| 4   | C/N Ratio | SL-MU-TT-05 (Bray I-II) | ppm | 1.71 | 1.92 | 3.49 | very low |
| 6   | *Ca       | SL-MU-TT-07 (Buffer NH4OAc 1.0 N pH 7.0) | cmol/kg | 1.07 | 1.10 | 1.64 | very low |
| 7   | *Mg       | SL-MU-TT-07 | cmol/kg | 1.68 | 1.49 | 2.59 | very low |
| 8   | *K        | SL-MU-TT-07 | cmol/kg | 5.81 | 2.69 | 3.09 | very low |
| 9   | *Na Total | SL-MU-TT-09 (KCl 1N) | cmol/kg | 1.47 | 0.17 | 0.71 | - |
| 10  | CEC       |           | cmol/kg | 28.9 | 55.4 | 83.8 | very low |
| 11  | Base Saturation |       | % | 1.5 | 33.7 | 60.9 | - |
| 12  | Al-H(exchangeable) | | % | 50.7 | 45.8 | 8.8 | - |
| 13  | Soil texture | Silt clay | | 47.8 | 20.5 | 30.3 | - |

The amount of soil water available for plants depends on the soil depth, that roots can explore the root zone and on the nature of the soil material. Because the total and available moisture storage capacities are linked to porosity, the texture and the arrangement of particles are the critical factors. Organic matter, carbonate levels, and pores content also affect moisture storage capacity. The major soil physical properties that might be significant for plant growth performance in the field area is about soil infiltration capacity and soil hydraulic conductivity. The slow movement of water due to the low value of permeability could inhibit the growing plant. Brownish soil had the highest pores structure (53.21 %). It means that the soil can absorb water faster than two other soil types. Soil permeability of brownish soil had the highest permeability of 20.37 cm/h, meanwhile, white pale soil had the lowest permeability of 1.31 cm/h, which is associated with higher runoff potential and waterlogging at a lower position.
Table 2. Soil physical properties

| Soil color | Bulk Density (g/cm³) | Total pores (%) | Water content at pF (%) vol | Drainage pore (%) vol | Water Holding Capacity (%) | Permeability (cm/h) |
|------------|---------------------|-----------------|---------------------------|----------------------|----------------------------|-------------------|
| White pale | 1.47                | 44.53           | 43.18                     | 42.36                | 32.41                      | 20.31             |
| Reddish    | 1.32                | 50.19           | 48.09                     | 44.67                | 37.42                      | 29.06             |
| Brownish   | 1.24                | 53.21           | 51.63                     | 43.20                | 41.31                      | 36.24             |

Result of X-Ray analysis for mineral clay presented in figure 1. The soil in the ex-borrow pit area was dominated by Kaolinite in all soil color, and a few Illit and Goethite. Kaolinite presented by top diffraction value between 7.06-7.12° A, Illit presented by top diffraction 10.1° A, and Goetit presented by top diffraction 4.1° A.

The soil was dominated by proximity 90% in mineral Kaolinite clay fractions. The dominance of this mineral indicates that the soil extremely lacks available soil nutrient potential. The chemical analyses showed that the content of macronutrients classified as very low. It indicates soil among the sites classified as critical soil type. The brownish soil contained clay mineral Goethite and Illit.

Figure 1. X-ray diffractogram of resultin reddish soil (T1), white pale soil (T2) and brownish soil (T3).

3.2. Vegetation growth performance
The shoot length of the *Mucuna* plant represents an indicator of plant growth. The length development of *Mucuna* planted on the degraded soil after seeding time reached 0.7-6.2 cm per day. The brownish soil showed the best performance for the growing media of the LCC-plant. Synthetic polymer emulsion application could improve the growth of the *Mucuna* plant. The shoot length reached 225.5 cm after 17 weeks in the reddish soil type, whereas under control treatment without synthetic polymer emulsion application, it reached averagely only 77.5 cm in equal time duration. The shoot length of *Mucuna bracteata* planted at white pale soil treated with synthetic polymer emulsion at the same time reached an average value of 143.8 cm. Without synthetic polymer emulsion application as control, the shoot length reached only 57.5 cm. On undegraded soil and in an optimum environmental condition for plants, the shoot elongation reaching 1.5 m from the seedling time required less than 2 months growing time [9] The shoot growth development of *Mucuna bracteata* with and without synthetic polymer emulsion application at the three soil color types is presented in figure 2A.
Land covering rate at the soil surface was considered as an indicator of reclamation successfulness. Step by step the growth of the plant in the field developed better. Averagely, after the application of synthetic polymer emulsion, soil surface covering rate on the three soil types increased from less than 2% at the beginning time to 16.5% in March, 22.6% in April, 27.1% in May, 33.5% in June, 45.5% in August, and became 86.7% on December 2010. Without application of synthetic polymer emulsion the soil surface covering rate reached only 7.5%, 11.3%, 16.3%, 20.1%, 19.5% and 41.7% respectively. *Mucuna bracteata* planting improves also soil bulk density, soil organic matter, and N-availability and soil infiltration [10]. The development of soil surface covered by *Mucuna bracteata* with and without synthetic polymer emulsion application at the three clay mineral soils is presented in figure 2B.

![Figure 2](image)

**Figure 2.** *Mucuna bracteata* elongation growth rate (A) and soil surface coverage (B) with and without synthetic polymer emulsion (Soil Sement®) application at three types of clay mineral soils.

4. Conclusion

An aqueous synthetic polymer is applicable for the mulching of surface soil for revegetation purposes to improve the growth of the cover crops. At critically degraded ex-borrow pit area, the elongation growth of *Mucuna bracteata* shoots on aqueous synthetic polymer spraying treatment reached 230% compared to without aqueous synthetic polymer spraying. Soil surface covering rate after the spraying application reached averagely 86.7% in ten months after planting. Without aqueous spray application, its covering rate reached only 41.7% in the same time duration. Application of aqueous synthetic polymer spraying at the soil with a higher content of Goethite and Illit clay mineral, instead of Kaolinite, showed better performance of the growth of legume cover crop and its soil surface coverage as well.

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