Utilization of bio-organo mineral as a soil ameliorant for hard crops

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Abstract. The research objective was to make a formula for economical complex soil conditioner of bio-organo mineral for tea, coffee and cacao plantations. The soil conditioner (SC) formula for such plantations was made by mixing the urea, phosphate, leucite and kieserite with the ratio of 25:7:12:3. The experiments at Block B5 showed the amount of harvested dormant leaves was 3.37 kg/100 m\textsuperscript{2} while the control yielded 2.29 kg/100 m\textsuperscript{2}. There is a difference around 1.08 kg/100 m\textsuperscript{2} or 47%. The amount of Peko shoots was 19.82 g/100 m\textsuperscript{2} when using the soil conditioner while the control had 14.89 g/100 m\textsuperscript{2} performing the difference 33% while at Block A10, the amount of harvested dormant shoot was 3.53 kg/100 m\textsuperscript{2}. There is a difference around 3.29 kg/100m\textsuperscript{2} or 7%. The amount of Peko shoot was 18.25 g/100 m\textsuperscript{2} while the control acquiesced 15.05 g/100m\textsuperscript{2} – the difference of both was 21%. The Robusta grew from 25.4 cm to 28.5 cm when using the BIOM-SC. but the plant height is only from 24.4 cm to 26.8 when using NPK fertilizer.

1. Introduction
The nutrients for plant production are major nutrients nitrogen (N), phosphor (P), and potassium with micro nutrients magnesium (Mg), calcium (Ca) and sulphur (S). All nutrients - exclude the nitrogen - can be provided by non-metallic mineral rocks such as phosphate rocks, potassium-bearing rocks, and dolostone. In Indonesia, the reserve of the three rocks are 23,334,510 tons; 455,000,000 tons; 7,171,927,000 tons respectively [1]. Such rocks can be processed and the applied to the plantation as an ameliorant.

Research Development Centre for Mineral and Coal Technology of Bandung has performed a research regarding a complex ameliorant since 2001. The ameliorant has been applied on tomato production using 300 kg/ha of ameliorant, the yield of vegetable is similar to the yield of vegetable grown with NPK-fertilizer around 900 kg/ha [2]. Another research dealing with mineral-based ameliorant is kieserite ameliorant for hard crops, namely palm oil, coffee, tea, rubber, and cocoa plantations. The research designs kieserite ameliorant with capacity of 10,000 tons a year [3]. Yet the single kieserite ameliorant only supplies for Mg and S. Other ameliorant for cultivating the plants is potassium ameliorant. The potassium is one of the micro-nutrients. The element accelerates the flowering and fertilization of the plants.
Mineral-based ameliorant is a mixture of phosphate, dolomite with sulphuric acid. To complete the minor elements, the ameliorant is added a few of B, Cu, Fe, Mn, Mo and Zn. The natural phosphate rocks have a lot of P and Ca while the dolomite rocks dominantly contain Mg and Ca. If the phosphate rocks are processed by adding the reactor agent and neutralized by dolomite will result a complex ameliorant with the pH of 6 -7 that consist of P, Ca, Mg, and S nutrients as well the micro nutrients of B, Cu, Mn and Zn that are easy to dissolve in the soil. The Fe and Mo micro nutrients are ready available within the rocks [4,5]. Figure 1 shows the illustration of processing the complex ameliorant.

By crushing and grinding Mineral rock phosphate, dolomite, leusite, organic into 80 mesh size. Combined with KCl, TSP and phosphate and potassium solubilizing microorganisms. Then mixed until homogeneous, pelleted and packaged the product.

Kieserite ameliorant contains magnesium sulfate. The Mg$^{2+}$ and SO$_4^{2-}$ ions are very useful for the plant growth. The natural magnesium sulfate may be found as *magnesium sulphate dihydrate* (MgSO$_4$.2H$_2$O) or hydrate and can be derived de-hydration of one of its hydrates. The known MgSO$_4$ in nature is MgSO$_4$.H$_2$O and occurs as kieserite and heptahydrate - MgSO$_4$.7H$_2$O or known as epsomite. Kieserite is an evaporate mineral as occurred due to sea water evaporation. Other evaporate salts refer to halite (NaCl), sylvite (KCl), carnalite (MgCl$_2$.6H$_2$O), and epsomite (MgSO$_4$.7.H$_2$O). Based on the SII no. 1128 year 1985. Kieserite ameliorant should have a dense crystal performance with minimum MgO of 25.5% and minimum sulphur of 21.0%. Its chemical characteristics include:

- chemical formula: MgSO$_4$.2H$_2$O;
- molar mass: 156 g/mol;
- easy to absorb the water;
- monoclinic;
- hardness: 3.5 Mohs scale;
- slow dissolution of the nutrients;
- neutral pH in a natural water.

Dolomite belongs to a double bond chemical compounds between calcium from the carbonate (CaCO$_3$) and magnesium of magnesite (MgCO$_3$). Another fertilizer required by vegetation is potassium ameliorant. Source of potassium comes from potassium chloride mineral (sylvite - KCl) or complex compound of (K, Mg)-chlorite and sulfate. Potassium ameliorant is easy to dissolve in water and the plant will absorb naturally the weathering of K mineral, compost and plant residue. The
potassium-bearing mineral includes K-feldspar, leucite, biotite, phlogopite, and glauconite as well as illite while the silicate rocks that is rich in potassium is the leucite-bearling volcanic rocks. The advantage of potassium in soil is securing the plant rigidity, stimulating the root growth, more resistant to pests and diseases, improving grain quality, reducing the effect of ripeness due to phosphor effect, overcoming water shortages at particular level. Decreasing potassium will result in dwarf growth, dry and burn on the sides leaves, inhibits formation of charcoal hydrate in seeds, uneven chlorotic symptoms on the leaf surface, spotting appearance on the dark green part of the leaf. The research objective is utilizing the phosphate and leucite potencies by adding the decomposing microbes of such mineral compound available within the two rocks in order to make the $\text{P}_2\text{O}_5$ and $\text{K}_2\text{O}$ nutrients absorbs by the plant roots. Another research objective is making a formula for making economical complex soil conditioner of bio-organo mineral that is capable to provide a good result for tea, coffee and cacao plantations. Bio organo mineral and bio mineral are part of ameliorants.

2. Materials and methods

The research was conducted for 3 months and uses one-way analysis of covariance (ANCOVA). The consideration using such a method is:

- 24 plots of experimental design. Each plot is made randomly to provide 6 treatments and results in 4 plots for each treatments;
- the experimental design is focussed to evaluate whether the ameliorant treatments provide the effect to the tea plantation;
- the ANCOVA is applied to observe the response variable on the production of the tea shoot by involving the influence of accompanying variable (the amount of Pekoe shoot). If such an adjustment is not accomplished, the accompanying variable can increase an error and the test experiments are not sensitive anymore.

2.1. Ameliorant application in tea plantation

A series of experiments had been conducted to evaluate the effect of bio-organo mineral formula on the tea, coffee and cacao plantations in a real condition in the field. Such the experiments were conducted at the Research Institute for Tea and Cinchona of Gambung and the Indonesian Coffee and Cocoa Research Institute of Jember. The effective ameliorant was tested on mature tea plantation at two different locations, namely Block B5 PPTK for GMB 7 clone and Block A10 PPTK for TRI clone [6]. The experiments applied randomized block design along with 6 treatments and 4 repetitions. Table 1 shows the experimental design.

| No. | Treatments                  | Fertilizer (per garden bed or 100 trees)                              |
|-----|-----------------------------|---------------------------------------------------------------------|
| 1   | Control                     | No fertilizer                                                      |
| 2   | Farm Standard (Single Fertilizer) | Urea (2.3 kg), SP-36 (0.7 kg), KCl (0.7 kg), ZnO$_2$ (28 gr), kieserite (0.75 kg) |
| 3   | Mineral                     | Urea (2.3 kg), kieserite (0.75 kg), phosphate (1.75 kg), leucite (4.7 kg) |
| 4   | Organo Mineral              | Urea (2.3 kg), kieserite (0.75 kg), phosphate (1.75 kg), leucite (4.7 kg), organic matter (950 ml) |
| 5   | Bio-organo Mineral          | Urea (2.3 kg), kieserite (0.75 kg), phosphate (1.75 kg), leucite (4.7 kg), organic matter (950 ml), bio-organo material (950 ml) |
| 6   | Bio Mineral                 | Urea (2.3 kg), kieserite (0.75 kg), phosphate (1.75 kg), leucite (4.7 kg), bio-organo material (950 ml) |
Each treatment of one garden bed needs a hundred of mature tea, therefore the required tea plantation for trials using bio-organo mineral ameliorant refers to 4,800 plants. The observed variables include weight of produced shoot (either Peko or dormant) in kg/100 m².

2.2. Ameliorant application in coffee and cacao seedling

Trials for the Robusta and Arabica coffee as well as cacao seedlings (in 3 months) were conducted at a green house on immature plants using 9 treatments and 3 repetitions (Table 2). Each treatment consisted of 10 plants so as each commodity owns 270 immature plants. The observed variables include:

- plant height;
- trunk diameter;
- leaf amount;
- biomass analysis at the end of observation.

| No. | Treatments                     | Fertilizer (g/polybag/application)                                      |
|-----|--------------------------------|------------------------------------------------------------------------|
| 1   | Control 1                      | Without fertilizer                                                    |
| 2   | Control 2                      | Single inorganic fertilizer                                            |
| 3   | Control 3                      | Inorganic fertilizer NPK 15:15:15                                       |
| 4   | Bio-organo Mineral (Full Recipe)| Urea (0.33 g), kieserite (0.57 g), phosphate (0.83 g), leucite (1.67 g), organic matter (0.34 g), bio (0.34 ml) |
| 5   | Organo Mineral (Full Recipe)   | Urea (0.33 g), kieserite (0.57 g), phosphate (0.83 g), leucite (1.67 g), organic matter (0.34 g) |
| 6   | Bio Mineral (Full Recipe)      | Urea (0.33 g), kieserite (0.57 g), phosphate (0.83 g), leucite (1.67 g), bio (0.34 ml) |
| 7   | Bio-organo Mineral (Half Recipe)| Urea (0.17 g), kieserite (0.28 g), phosphate (0.42 g), leucite (0.83 g), organic matter (0.17 g), bio (0.17 ml) |
| 8   | Organo Mineral (Half Recipe)   | Urea (0.17 g), kieserite (0.28 g), phosphate (0.42 g), leucite (0.83 g), organic matter (0.17 g) |
| 9   | Bio Mineral (Half Recipe)      | Urea (0.17 g), kieserite (0.28 g), phosphate (0.42 g), leucite (0.83 g), bio-organo material (0.17 ml) |

Measurement of each variable is conducted manually during application as an initial data. Next observation occurred every month during six months of the experiments. The data were used for calculating the productivity of bio-organo mineral compared to the use of fertilizer in the market and another supporting information [7]. A series of stages in assessing the bio-organo mineral ameliorant in the field includes preparation raw material for ameliorant, making ameliorant, and trials in the field on either tea mature plants or coffee and cacao immature plants. Conducted at Testing Laboratory of the Research Development Centre for Mineral and Coal Technology, analyzing chemical composition is the first step in ameliorant making. Around 26.6% of MgO is available within kieserite. The figure is in accordance with kieserite MgO on the market. The potassium from leucite (in the form of K₂O) is only 7.81%. This fact is far enough from the synthetic potassium that can be reached 60% of K₂O. However, such the mineral can still be substituted the synthetic potassium. The phosphate rock contains 20.30 – 28.8% P₂O₅, such a figure is very adequate as phosphate fertilizer while the nitrogen still relies on the urea with 46% N₂ as there is no mineral with a high content of nitrogen.

The organic materials used as raw material for ameliorant making included feces and urine of the sheep. Both sample types were analyzed at Testing Laboratory for Tea and Cinchona at the Research Institute for Tea and Cinchona of Gambung using titration method for total nitrogen and organic carbon while the Mn, Zn, and B used AAS method. Test of organic material was accomplished to determine the potency of substrate that will be used for bacterial growth or supporting material for mineral-based
ameliorant that can increase soil fertility. The nitrogen content within the feces of sheep is relatively high, namely 2.46% while the similar element in the urine of sheep is relative small (0.0392%). The organic carbon within the feces is also relative high (6.88%) similar to the micro elements (Mn, Zn, and B). The three micro elements perform 520, 83.1, and 73.49 ppm.

The microbes used as one of raw materials for ameliorant making were reproduced separately within sterile molasses with concentration of 5% at room temperature. Its incubation took 5 days and at the end of incubation time the bacterial population is counted using a Total Plate Count and a Most Probable Number Durham [8,9]. The microbe population applied for bio-enhancer is equalized to make it uniform and sample to be analyzed is a solution comes from the breeding result of bacterial consortium within molasses solution to evaluate the contained bacterial. It is shown that *Azotobacter sp.* retains the highest population among the analyzed micro-organism, namely $6.20 \times 10^5$ followed by endophytic bacteria ($7.65 \times 10^9$) and phosphate solubilizing microorganism ($8.20 \times 10^9$). *E. coli* bacteria and *Salmonella sp.* are not available within the samples [10–13]. The amount of microbes is already appropriate for tea, coffee and cacao plantations. The equipment used for making bio-organo mineral ameliorant includes jaw crusher, hammer mill, and carbon mixer as well the electric power for generating the equipment. A formulation for bio-organo mineral ameliorant is made for the produce tea plant (TM) as well as immature coffee and cacao plants.

The ratio of N (urea): P (phosphate): K (leucite): Mg (kieserite) is 25 : 7 : 12 : 3 and the required micro-organism and organic materials is 10% of the amount ameliorant per application [14]. The used microbe is in the liquid form while the organic material is the mixture of the liquid and the solids [15]. Kieserite, phosphate, and leucite are prepared by crushing such the materials using a jaw crusher and followed by grinding them in a ball mill. The last process of preparing material for ameliorant raw material is sieving such the material by a vibrating screen.

3. Results and discussion

3.1. Results from tea experiment

3.1.1. Fertilizer test on the produce tea plant (TM). The test was accomplished at the Research Institute for Tea and Cinchona of Gambung at Block A10 and B5 using different type of tea plantations, namely clone TRI at Block A10 and clone GMB 7 at Block B5. The observation was focused on production weight of shoot, amount of shoot, and weight per shoot. Table 3 and Figure 2 represents the production weight of the dormant shoot per plot at Blok B5. The table shows that the highest production mean occurs after 10 X picking using bio organo-mineral ameliorant (3.37 kg/100 m$^2$) and the smallest production belongs to that of control treatments, namely 2.29 kg/100 m$^2$.

Meanwhile the production weight of the Peko shoot per plot at Blok B5 shows the highest production belongs to the treatment using the organo-mineral ameliorant (19.82 g/100m$^2$; Table 3) while the smallest is achieved by treatment using no control (14.89 g/100m$^2$).

Studying the effect of fertilizer treatments on the achieved weight of dormant shoots in Block B5 shows that the highest weight of the average for ten time picking belongs to the treatment using bio organo-mineral ameliorant, namely 1.64 g/ shoot followed by the tea plants that have bio-mineral ameliorant treatment (1.59 g/shoot). Other tea plantation that have a treatment with various fertilizers shows less weight of the dormant shoot (< 1.55 g/shoot). Similar condition also occurs to the weight of Peko shoot. When treated by bio organo-mineral ameliorant produces the weight of the Peko shoot bigger than the weight of the Peko shoot from other treatments, while production weight of the dormant and Peko shoots per plot at Blok A10 is shown in Table 4 and Figure 3.
Table 3. Production weight of the dormant shoot and per plot at Blok B5.

| Treatments                      | Preliminary mean | Mean of 3x Picking | Mean of 10x Picking | Preliminary mean | Mean of 3x Picking | Mean of 10x Picking |
|---------------------------------|------------------|--------------------|---------------------|------------------|--------------------|---------------------|
| Control/ no fertilizer (KTP)    | 2.36              | 1.40               | 2.29                | 15.15            | 8.77               | 14.89               |
| Standard fertilizer (PSK)       | 2.63              | 1.63               | 2.93                | 16.01            | 10.77              | 17.18               |
| Mineral fertilizer (PM)         | 2.72              | 1.90               | 3.24                | 19.68            | 10.72              | 18.67               |
| Organo-mineral fertilizer (POM) | 2.38              | 1.47               | 2.87                | 19.53            | 13.60              | 19.82               |
| Bio organo-mineral fertilizer (PBOM) | 2.98          | 1.80               | 3.37                | 16.60            | 12.46              | 18.92               |
| Bio-mineral fertilizer (PBM)    | 3.16              | 1.57               | 3.13                | 20.37            | 11.79              | 18.11               |

Figure 2. Production of dormant shoot (a) and Peko shoot (b) per plot at Blok B5.

Table 4. Production weight of the dormant and Peko shoots per plot at Blok A10.

| Treatments                      | Preliminary mean | Mean of 3x Picking | Mean of 10x Picking | Preliminary mean | Mean of 3x Picking | Mean of 10x Picking |
|---------------------------------|------------------|--------------------|---------------------|------------------|--------------------|---------------------|
| Control/ no fertilizer (KTP)    | 5.23              | 5.12               | 3.29                | 9.74             | 14.64              | 15.05               |
| Standard fertilizer (PSK)       | 5.76              | 5.96               | 4.10                | 11.39            | 15.81              | 19.28               |
| Mineral fertilizer (PM)         | 4.70              | 5.75               | 3.59                | 9.15             | 14.00              | 17.71               |
| Organo-mineral fertilizer (POM) | 4.76              | 5.55               | 3.53                | 9.92             | 12.84              | 15.71               |
| Bio organo-mineral fertilizer (PBOM) | 5.67          | 4.81               | 3.22                | 8.57             | 11.90              | 16.33               |
| Bio-mineral fertilizer (PBM)    | 4.55              | 4.75               | 3.12                | 9.12             | 13.34              | 18.25               |

Figure 3. Production of dormant shoot (a) and Peko shoot (b) per plot at Blok A10.
Observation on the amount of the dormant shoot and Peko shoot finds several items as follows:

- the highest production mean occurs after 10 X picking using standard fertilizer (21.18 kg/100m²) and the smallest production belongs to that of control treatments, namely 2.29 kg/100m² and the smallest production belongs to that of control treatments, namely 17.76 kg/100m²;
- a treatment using several fertilizers, only those that use mineral and bio-mineral ameliorant retain the high result (21.18 and 20.45 kg/100m²);
- a treatment using bio organo-mineral and bio mineral only reach 19.03 and 19.27 kg/100m² respectively;
- it seems that treatment the area using standard fertilizer is much better than others;
- similar condition occurs to the amount of Peko shoot, the area without fertilizer (control) retains the highest amount of Peko shoot at Block B5 (32.6 kg/100m²), the area with bio organo-mineral only gets the amount of Peko shoot around 27.1 kg/100m².

3.2. Results from coffee and cacao experiment

A series of tests to the coffee and cacao plants treated by bio organo-mineral fertilizers was conducted in a greenhouse at the Indonesian Coffee and Cocoa Research Institute of Jember. The research was focused on the amount of leaf and height of the plant. Experiments for Robusta coffee plants were conducted for three months by observing the most widely leaves in the coffee plants that were treated bio-organo mineral ameliorant no. 4 – the ameliorant that has complete nutrient elements. It shows that the amount leaves are sufficient compared to those treated with the NPK standard (Treatment no, 3). Yet to get the highest tree of the Robusta coffee, the best bio-organo mineral composition was used a half recipe of Treatment no. 7 (Table 5 and Figure 4).

A 3-month trial on Cocoa observed the most leaves and plant height. It showed that the test using bio-organo mineral treatment no. 4 - the most complete in nutrients both in composition and quantity – provided the best results compared to those used single fertilizer treatment no 2 (Table 6 and Figure 5).

### Table 5. Observation of the number of leaves and plant height on robusta coffee.

| Treatment | Robusta Coffee |
|-----------|----------------|
|           | Amount of leaves | Height of Plant (cm) |
|           | July | August | September | July | August | September |
| 1         | 11.67 | 11.97 | 14.00 | 26.68 | 27.34 | 29.22 |
| 2         | 11.00 | 10.93 | 13.83 | 24.25 | 24.45 | 25.65 |
| 3         | 10.73 | 9.93  | 11.20 | 24.42 | 24.88 | 26.87 |
| 4         | 11.27 | 10.97 | 14.73 | 25.96 | 26.44 | 26.63 |
| 5         | 9.77  | 9.73  | 12.57 | 24.38 | 24.91 | 27.72 |
| 6         | 11.63 | 10.60 | 12.97 | 23.84 | 24.31 | 27.75 |
| 7         | 10.47 | 10.30 | 11.93 | 25.43 | 25.04 | 28.50 |
| 8         | 11.20 | 10.97 | 13.07 | 25.25 | 25.07 | 26.50 |
| 9         | 9.87  | 10.43 | 11.60 | 25.64 | 25.25 | 27.21 |
Figure 4. Amount of leaf (a) and height (b) ratios for robusta coffee plant.

Table 6. Observation of the number of leaves and plant height on Cacao.

| Treatment | Amount of leaves | Height of Plant (cm) |
|-----------|------------------|---------------------|
|           | July  | August | September | July  | August | September |
| 1         | 7.90  | 11.60  | 14.27     | 20.08 | 24.80  | 31.06     |
| 2         | 7.40  | 11.17  | 12.60     | 20.86 | 24.75  | 29.69     |
| 3         | 7.57  | 11.27  | 13.27     | 20.53 | 25.51  | 31.48     |
| 4         | 7.47  | 10.93  | 13.43     | 21.21 | 26.30  | 32.43     |
| 5         | 6.93  | 10.23  | 12.47     | 20.35 | 25.35  | 30.36     |
| 6         | 7.20  | 10.50  | 13.13     | 18.67 | 23.89  | 30.34     |
| 7         | 7.03  | 10.53  | 12.60     | 20.23 | 26.21  | 30.33     |
| 8         | 7.43  | 10.80  | 13.10     | 19.69 | 25.23  | 29.48     |
| 9         | 7.63  | 10.83  | 13.53     | 20.08 | 25.43  | 31.69     |

Figure 5. Amount of leaf (a) and height (b) ratios for Cacao plant.

4. Conclusions
The formulation of ameliorant for the produce tea plant (TM) and immature coffee and cacao plants (TBM) as well is already available. Results of the formula is good enough for tea, coffee, and cacao plantations. It needs to increase the program from a laboratory scale to a pilot plant for tea plantation, an industrial-scale partnership, however, for coffee and cacao plants, it is better to perform several tests to the producing plants (TM) as the result will be measurable in the form of coffee beans and cacao.
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