Potential of mineral resources as an alternative raw material for K fertilizer

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Abstract. Indonesia has potential mineral deposits of leucite, phlogopite, biotite, and trachyte which could be explored as an alternative raw material for K fertilizer. The objective of the study was to evaluate K content of various rocks that were potential to be used as an alternative source of K fertilizer. The study of K nutrient solubility from finely ground eight rock types was done using incubation experiment under laboratory conditions. Treatments included control, heating, alkali fusion, heating followed by humic substance addition, heating followed by manure compost, humic and compost without heating. After incubation for 6 months, solubility of potential K (25% HCl extract) and available K (2% citric acid extract) were determined. The results showed that K₂O content of various rocks varied from 1.26 to 8.10% with the highest value of 8.10% shown by leucite-bearing rocks of Situbondo followed by 7.06% for leucite Pati, 6.50% for andesite Jepara, 5% for trachyte-andesite Barru, 4.58% for granite Sijunjung, 3.59% for andesite Lebak, 2.73% for liparite Gayo Luwes and 1.26% for schist and dolomite Sanggau. Alkali fusion treatment of leucite Situbondo and Pati increased K availability by 81 and 49%, respectively compared to a control at first month incubation. Humic substances and manure compost treatment did not have significant differences on potential and available K. The implication of the study is only two rocks (Situbondo and Pati) out of eight rocks are promising and potential to be used as an alternative source of K fertilizer.

1. Introduction
The production of inorganic fertilizers has some problems, such as lack of gas supply to produce urea, dependence on raw materials from abroad to produce P and K as KCl fertilizer should be imported. Inorganic fertilizers require the availability of raw materials that are limited and not renewable like natural gas, natural phosphate, and fertilizer source K-rock. It is therefore necessary to find alternative raw materials in Indonesia such as mineral deposits containing high K nutrient. The K fertilizer has created an opportunity to use the potential mineral deposits as source materials for K, that may offer alternative raw materials if K fertilizer supply is limited or difficult to find.

Indonesia has the potential mineral deposit of materials that can be explored as an alternative K-rock raw material. Minerals containing K nutrient such as Felspar mineral, mica (biotite, muscovite and phlogopite) and leucite, trachyte of natural rocks could contain K₂O (5-10 %). Deposit mineral containing K₂O around 5-10% can be explored and used as an alternative raw material for K fertilizer. The content of K₂O in mineral deposits in some locations could provide information for the local government/users to explore the mineral deposits as an alternative source of K fertilizer. However, the solubility and K nutrient supply capacity from the mineral deposits need to be known as a basic information to select the rock types that are promising for application in agriculture. K solubility of mineral rocks can be improves using physical, chemical and biological techniques to provide added value and to lower application dose of natural minerals of rocks. The formulation of NPK compound fertilizers could be made using K source from mineral rocks.
The mineral rock deposits distributed mostly in Java, Sumatra and Sulawesi [1]. Feldspar consisting of mineral anorthite, bytownite, labradorite, oligoclase, andesine, orthoclase and sanidin occurred in Nangro Aceh Darussalam, North Sumatra, West Sumatra, Bengkulu, Lampung, Banten, West Java, Central Java, East Java, East Nusa Tenggara, West Kalimantan, Gorontalo, Central Sulawesi and South Sulawesi in a quite high hypothetical amount of resources. Although the use of raw materials as a source of K fertilizer may compete with ceramic industrial raw materials, the selection of rocks for K fertilizer could be directed only for high K$_2$O content, therefore the low K$_2$O content of mineral rocks can be used as raw materials for ceramic industry. Potassium in leucite rocks could be found in the Bungatan District, Situbondo regency, with a potential deposit of 117.5 million tones [2]. The natural rock can be used as K fertilizer if K$_2$O content is 5-10%. Trachyte is a mineral containing 5.36% K$_2$O with hypothetical resources of 433.4 million tons and could be found in Kajura, Salemeko, Tonra, Bone regency. At present, the mineral materials are widely used as raw materials of white ceramic [1]. Potassium is the third macro nutrients required by plants. The source of K in the soil derived from weathering of the primary minerals contained K such as felspar, leucite, biotite, phlogopite, and muscovite [3][4]. Potassium plays an important role in the regulation of the osmotic potential in plant and activation of several enzymes involved in the process of photosynthesis and respiration [5]. Potassium is an essential nutrient because it has an important role in any process of plant physiology [5][6]. Application of mineral rock containing feldspar, illite, muscovite and biotite inoculated with solubilised K microbes also significantly increased yield and K uptake in wheat, tomato, chili, and peanut in the field experiment [7][8][9][10].

Utilization of mineral in natural rocks is expected to substitute partially KCl fertilizer and further improve soil properties, crop productivity, farmer income and local government revenues. The objective of the study was to evaluate K content of various rocks that were potential to be used as an alternative source of K fertilizer. Various rocks with high K-bearing minerals were collected from Situbondo (East Java), Pati and Jepara (Central Java), Sijunjung (West Sumatra), Sanggau (West Kalimantan), Gayo Luwes (Nangroe Aceh Darussalam), Lebak (West Java) and Barru (South Sulawesi) provinces and were used to determine K released from powder rock under laboratory incubation.

2. Methods

Eight rock materials with high K-bearing minerals were collected from Situbondo (East Java), Pati, and Jepara (Central Java), Sijunjung (West Sumatra), Sanggau (West Kalimantan), Gayo Luwes (Nangroe Aceh Darussalam), Lebak (West Java) and Barru (South Sulawesi) provinces. The study of K nutrient solubility from various rocks was tested using incubation experiment in the laboratory. Several techniques used were physical and chemical treatments to increase the purity of K$_2$O released from the rocks. All rocks were finely ground to 53 µm particle size and their total chemical constituents were determined using X-ray fluorescence (XRF) analyses. Only rocks with total K$_2$O content of more than 5% were selected for laboratory incubation to determine their nutrient solubility. Finely ground rocks was transferred into the pots and incubated for 6 months.

Alkali fusion was a process used to separate certain elements from silicate compounds. For this reason alkaline fusion was used to separate potassium from silicate minerals [11]. The process was done by finely ground rocks into powder and mixed with alkaline sources, namely NaOH with the amount of stoichiometric SiO$_2$ levels in the mineral materials. It was then heated using a furnace at temperature around 700 - 750°C for 2 hours. The results obtained were washed with water, and filtered to separate minerals potassium (residue) and Na-silicate (filtrate). Potassium mineral residues obtained were used for laboratory experiment to increase the solubility of K from mineral materials in alkaline fusion treatments.

Experimental design used was a randomized complete design with 7 treatments and 3 replications. Treatments included control, heating, alkali fusion, heating followed by humic substance addition, heating followed by manure compost, and humic and compost without heating.
As much as 350 g rocks powder was transferred into plastic jars, then added with distilled water to field capacity. The amount of 70 g of cow manure and 7 g (10% of manure doses) of humic compounds were added to the powder rock. The dose of humic compounds based on the composition of humic capacity. The amount of 70 g of cow manure and 7 g (10% of manure doses) of humic compounds were added to the powder rock. The dose of humic compounds based on the composition of humic compounds in organic matter, ranges-about 10-20% (w/w) [12]. The treated rocks powder were mixed evenly and incubated for 6 months in the laboratory. During incubation the water content was maintained at field capacity. Observations were made at 1, 3 and 6 months of incubation. After incubation for 1, 3 and 6 months, solubility of available K were determined using 2% citric acid extractant. Significant differences between treatments was determined using Duncan Multiple Range Test at 5% level [13].

3. Results and Discussions

K-bearing mineral rocks from 8 locations show that K₂O content ranged from 1.26 to 8.10% (Table 1). The highest K₂O value of 8.10% was shown by leucite-bearing rocks of Situbondo followed by 7.06% for leucite Pati, 6.50% for andesite Jepara, 5% for trachyte-andesite Barru, 4.58% for granite Sijunjung, 3.59% for andesite Lebak, 2.73% for liparite Gayo Luwes and 1.26% for schist and dolomite Sanggau. Only two rocks (Situbondo and Pati) out of eight rocks are potential to be used as an alternative source of K fertilizer.

Total SiO₂ content as determined by XRF of various rocks varied between 12.96 and 75.11% with the highest values for rocks powder of Gayo and Lebak; the lowest for Sanggau (Table 1). K-bearing mineral rocks from Sanggau and Pati contained CaO and MgO higher than others. In general P₂O₅ content ranged from 0.019 to 1.04 %, which were rated lower. K-bearing mineral rocks from Pati contained higher Fe oxide, while K-bearing mineral rocks from Jepara and Situbondo contained higher Al oxide (Table 1). The rocks powder from Sanggau showed the highest value (34%) for loss of ignition (LOI), indicating the material contains the high amount of volatile materials.

Table 1. X-Ray fluorecense analysis of various K-bearing mineral rocks from 8 locations

| No. | Elemental Oxide | Location          |
|-----|----------------|-------------------|
|     | Pati | Jepara | Sijunjung | Sanggau | Gayo | Lebak | Situbondo | Barru |
| 1.  | SiO₂ (%) | 46.70 | 63.10 | 70.90 | 12.96 | 75.11 | 74.76 | 48.88 | 63.20 |
| 2.  | Al₂O₃ (%) | 15.26 | 20.57 | 14.51 | 2.18 | 14.86 | 13.61 | 20.65 | 16.94 |
| 3.  | Fe₂O₃ (%) | 10.28 | 1.30 | 3.08 | 1.30 | 0.57 | 1.17 | 6.27 | 3.25 |
| 4.  | TiO₂ (%) | 0.464 | 0.071 | 0.31 | 0.15 | 0.013 | 0.13 | 0.309 | 0.36 |
| 5.  | K₂O (%) | 7.06 | 6.50 | 4.58 | 1.26 | 2.73 | 3.59 | 8.10 | 5.00 |
| 6.  | CaO (%) | 9.73 | 0.54 | 2.09 | 28.98 | 0.46 | 0.74 | 4.97 | 3.11 |
| 7.  | MgO (%) | 4.49 | 0.032 | 0.59 | 19.47 | 0.16 | 0.037 | 1.72 | 0.77 |
| 8.  | P₂O₅ (%) | 1.04 | 0.022 | 0.098 | 0.027 | 0.039 | 0.019 | 0.274 | 0.22 |
| 9.  | Na₂O (%) | 2.19 | 5.62 | 3.34 | 0.006 | 5.04 | 4.35 | 3.83 | 4.26 |
| 10. | MnO (%) | 0.190 | 0.003 | 0.052 | 0.018 | 0.008 | 0.008 | 0.166 | 0.080 |
| 11. | LOI (%) | 3.52 | 2.14 | 0.34 | 33.64 | 0.94 | 1.24 | 5.00 | 1.91 |

Note: LOI = loss of ignition

The available K of rocks powder from Situbondo achieved maximum value after one month (Fig. 1), while trachyte-andesite Barru, andesite Pati and Jepara achieved it after six months of incubation (Figs 2, 3 and 4). The rocks powder from Situbondo contained higher total K₂O and were more soluble than other rocks powder.
Figure 1. Available K released from K-bearing mineral rocks of Situbondo at different incubation periods

Figure 2. Available K released from K-bearing mineral rocks of Pati at different incubation periods

Figure 3. Available K released from K-bearing mineral rocks of Barru at different incubation periods
In all rocks powder and treatments, the alkali fusion treatment showed the high solubility of K. It indicated that the fusion could speed up K released from rocks powder. Alkali fusion treatment of rocks powder from Situbondo and Pati increased available K by 81% compared to the control after one month incubation (Fig 1). Alkali fusion treatment of rocks powder from Pati, trachyte-andesite Barru and Andesite Jepara increased available K by 49%, 98% and 97%, respectively compared to the control after six months of incubation (Figs 2, 3 and 4). The alkali fusion treatment promoted high K solubility, because the heating process released the K bond and the potassium will separate from silicate minerals during fusion process resulted the high K content. Humic substances and manure compost did not have significant effect on K availability of rocks powder. It was suspected that humic compounds and manure application needed a longer period (> 1 month) to dissolve K from rocks powder [14].

4. Conclusion

K$_2$O content of various rocks varied from 1.26 to 8.10% with the highest value of 8.10% occurred in leucite-bearing rocks from Situbondo followed by 7.06% for leucite Pati, 6.50% for andesite Jepara, 5% for trachyte-andesite Barru, 4.58% for granite Stijunjung, 3.59% for andesite Lebak, 2.73% for liparite Gayo Luwes and 1.26% for schist and dolomite Sanggau. Alkali fusion treatment of leucite Situbondo and Pati increased K availability by 81 and 49% respectively compared to control after first month of incubation. Alkali fusion treatment of trachyte-andesite Barru and andesite Jepara increased K availability by 98 and 97% respectively compared to control after six months incubation. The K availability of leucite Situbondo achieved maximum value after one month of incubation, while trachyte-andesite Barru, andesite Pati and Jepara occurred after six months of incubation. Humic substances and manure compost did not have significant effect on K availability. Only two rocks (Situbondo and Pati) out of eight rocks are potential to be used as an alternative source of K fertilizer

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