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Applications of guano and K_2CO_3 on soil potential-P, potential-K on Andisols

K Zakiah[1], M R Maulana[2], L R Widowati[1] and J Mutakin[2]

[1] Indonesian Soil Research Institute, Bogor, Indonesia
[2] Faculty of Agriculture, Garut University, Garut, Indonesia

E-mail: kiki.alzakia@gmail.com

Abstract. The source of phosphorus and potassium for plants, which commonly from inorganic fertilizer, can be replaced by other sources such as Guano and K_2CO_3. Guano is organic material rich in P and other soil nutrients, which has the function as well as rock phosphate. Furthermore, potassium carbonate (K_2CO_3) has 56% of K, higher than KCl, which only has 52% so it has potential as a source of K for plants. This study aimed to find out the dose of Guano and K_2CO_3 as an alternative of P and K fertilizer on soil potential-P, potential-K, and soil reaction (pH). The experiment was conducted at Situgede Garut – West Java with an altitude of 1,200 m above sea level with soil reaction 6.05. The experiment was conducted from April to July 2018. The method used was a Randomized Block Design with nine treatments and three replications. The experiment result showed the value of soil potential-P (P_2O_5 HCl 25%) and potential-K (K_2O HCl 25%) due to treatment of Guano and K_2CO_3 statistically no difference to with treatment of NPK standard. Therefore, K_2CO_3 and guano have potentially been used as a fertilizer compound.

1. Introduction

Soil is a non-renewable natural resource. From an edaphology perspective, soil plays an essential role as a medium for plant growth and as a source of nutrients for plants. Andisols are a type of soil with a high fertility rate and are suitable for most horticultural crops. This soil originates from the main material of the volcano and is usually found in highland areas. Therefore the farming system on Andisols is related to the farming system in the highlands. One of the crops that is widely cultivated in the highlands is the potato plant. Potato suitable and grow optimally at an altitude >700 m above sea level [1,2]. Potatoes are an essential crop commodity in Indonesia, but their productivity is low, about 5 to 20 t ha^{-1}.

Andisol soil from Cigedug, Garut, West Java used in this study has a low value of Potassium (K) so it is necessary to add K fertilizer. K elements can be obtained from both organic and inorganic fertilizers. Some plants, such as potato require P and K higher than other plants. The inorganic K fertilizer that was commonly used as potassium chloride (KCl). However, another potassium source that can be used as K fertilizer for plants is potassium carbonate (K_2CO_3). Potassium carbonate containing 56% K, which is higher than KCl which only has 52% so that it can be a source of K for plants. Substitution of K fertilizer with K_2CO_3 can be done to avoid the harmful effects of excessive chlorine due to massive KCl additions. Potassium carbonate (K_2CO_3) is a salt compound that can dissolve in water but does not dissolve in ethanol, forming strong alkalis. Potassium carbonate is produced by the reaction of potassium hydroxide with carbon dioxide.

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Another element that is needed in large quantities by potato plants is phosphorus (P). On the other hand, although Andisols are the soil that can be said to be fertile for agriculture, retention P in this soil is high. P retention in Andisols causes P elements difficult to be absorbed by plants. So far, farmers still rely on P fertilizers from inorganic fertilizers such as SP-36, MAP, DAP, or NPK fertilizer compounds. The use of inorganic fertilizers continuously can impact soil compaction and reduction of organic matter layer in the soil. It is necessary to find other alternative sources of P that can replace the function of inorganic P fertilizers that can support sustainable agriculture.

Guano can be categorized as natural phosphate. In nature, phosphate concentrations are a result of freezing, precipitation, weathering, and biological processes. Guano deposits are divided into two forms, cave deposits, and insular deposits. Cave deposits are formed by bat droppings and are frequently formed by bird droppings or small vertebrates remains. Several things caused the formation of this cave deposit, namely: 1) the presence of bedrock suitable for cave formation, such as limestone and dolomite, 2) warm and wet climatic conditions that support the proliferation of bats in large numbers. Meanwhile, island deposits are formed either directly or indirectly by seabird droppings and are generally found in warm-dry or semiarid areas where there are large bird populations, both at that time and in the previous period [1].

The nutrient contained in Guano is nitrogen (N), phosphorus (P), and calcium (Ca), besides that Guano also contains potassium (K), magnesium (Mg), and sulfur (S). The levels of these elements in Guano vary depending on the degree of climatic destruction and leaching [3].

2. Materials and methods

2.1. Site and time

This research was conducted in Situgede Village, Cigedug District, Garut City at an altitude of 1,200 m above sea level with Andisols soil type and soil reaction (pH) of 6.05. The experiment was conducted from April to July 2018.

2.2. Materials and experimental design

The materials used consisted of potato seeds Var. Atlantic, organic fertilizer (manure) as base fertilizer, urea, SP-36, KCl, potassium carbonate (K_2CO_3), and guano.

The experimental design used was randomized block design (RBD) consisting of nine treatments and repeated three times. The nine treatment combinations:

A = control (without fertilizer)
B = 2.93 g Urea + 1.80 g KCl + 3.61 g SP-36
C = 1.47 g Urea + 0.84 g K_2CO_3 + 2.71 g guano
D = 2.93 g Urea + 0.84 g K_2CO_3 + 2.71 g guano
E = 2.93 g Urea + 0.84 g K_2CO_3 + 5.42 g guano
F = 2.93 g Urea + 1.67 g K_2CO_3 + 5.42 g guano
G = 2.93 g Urea + 1.67 g K_2CO_3 + 1.81 g SP-36 + 5.42 g guano
H = 2.93 g Urea + 1.67 g K_2CO_3 + 3.61 g SP-36
I = 2.93 g Urea + 1.67 g K_2CO_3 + 8.13 g guano

The experimental plot size was 1 m x 0.8 m with a 30 cm x 40 cm plant distance. Each plot was planted with six crops of potatoes. Therefore, the total number of potato plants was 162.

The parameters consisted of soil potential-P, potential-K, pH, and the number of tubers per plant. Potential P and K and soil pH were measured by taking soil samples per plot after harvest. Measurements of soil potential P and K at the laboratory using 25% HCl extraction. The number of tubers per plant is the average number of tubers from plant samples at the experimental plot. Number of tuber was observed at 90 days after planting (DAP).

3. Results and discussion

3.1. Soil analysis

Soil analysis at the site before the experiment is present in table 1. Table 1 showed that the soil reaction (pH) was slightly acidic. It is essential to adding soil ameliorant that could increase the soil pH. Both P-potential and available P is very high, thought to intensive farming carried out in the site that caused a P residue. In contrast to P, the potential K value is low therefore requires K fertilizer.

Table 1. The result of initial soil analysis.

Parameter	Unit	Result	Criteria*
pH H_2O	-	6.05	Slightly Acidic
pH KCl 1 N	-	5.45	-
Organic-C	(%)	2.61	Moderate
Total N	(%)	0.31	Moderate
C/N	-	8	Low
P_2O_5 HCl 25%	(mg 100 g^{-1})	78.62	Very high
P_2O_5 Bray	(ppm)	24.48	Very high
K_2O HCl 25%	(mg 100 g^{-1})	19.43	Low
Cation:			
Exchangeable K	(cmol kg^{-1})	0.89	High
Exchangeable Na	(cmol kg^{-1})	0.40	Moderate
Exchangeable Ca	(cmol kg^{-1})	8.03	Moderate
Exchangeable Mg	(cmol kg^{-1})	0.38	Low
CEC	(cmol kg^{-1})	11.78	Low
Base Saturation	(%)	82.34	Very High
Exchangeable Al	(cmol kg^{-1})	0.19	-
Exchangeable H	(cmol kg^{-1})	0.62	-
Al Saturation	(%)	1.80	Very Low
Texture:			
Sand	(%)	50	
Silt	(%)	32	Loam
Clay	(%)	18	

Description : Chemical Analysis from Laboratory of Soil Fertility and Plant Nutrition, Department of Soil Science, Faculty of Agriculture, UNPAD (2018).
Source : [4].

3.2. Soil potential P

The results of the experiment (table 2) show that treatment A (control) was not significantly different from treatment C, D, F, H, and I, but significantly different from treatment B, E and G. Treatment E (2.93 g urea + 0.84 g K_2CO_3 + 5.42 g guano) showed the highest value for the P-potential value although statistically not significantly different from treatment B (2.93 g urea + 1.80 g KCl + 3.61 g SP-36), D (2.93 g urea + 0.84 g K_2CO_3 + 2.71 g guano), and G (2.93 g urea + 1.67 g K_2CO_3 + 1.81 g SP-36 + 5.42 g guano). These results indicate that soil potential P due to K_2CO_3 and guano use is similar to the standard dose of inorganic fertilizers (urea, SP-36, and KCl) commonly used by farmers. In this case, guano can substitute inorganic fertilizers and increase the soil potential P from 78.62 mg 100 g^{-1} (based on initial soil analysis result).

Table 2. Soil potential P.

Treatments	Potensial P (mg $100g^{-1}$)[a]
A	17.49 a
B	202.8 b
C	49.62 a
D	167.46 ab
E	283.16 b
F	125.61 a
G	175.25 b
H	124.99 a
I	17.86 a

Note: [a] The average number in the column marked with the same letter shows no significant difference according to Duncan's Multiple Range Test at the 5% level.

This increase in potential-P can occur directly and indirectly. Directly, applying a certain amount of guano to the soil will increase the source of organic P. At the same time the indirect effect is the result of P release from soil colloids and soil adsorption complexes. Guano also contains 19% phosphorus in the form of P_2O_5 needed to build ATP compounds in the photosynthetic process for the formation of carbohydrates [5,6]. The significance of phosphate reaction may vary with fertilizer material, moisture, soil, temperature and time [7].

3.3. Soil potential K

Based on statistical analysis, treatments C gave the highest value to the soil potential K (1.47 g urea + 0.84 g K_2CO_3 + 2.71 g guano), E (2.93 g urea + 0.84 g K_2CO_3 + 5.42 g guano) and H (2.93 g urea + 1.67 g K_2CO_3 + 3.61 g SP-36). Treatment C, E, and H resulting higher values than treatment B (2.93 g urea + 1.80 g KCl + 3.61 g SP-36), although they were not statistically significant. This value has increased when compared with the results of soil potential K analysis before the experiment, which has a value of 19.43 with low criteria.

K_2CO_3 can increase the potassium content in the ground. The results of this study prove that K_2CO_3 has the potential to substitute for K fertilizer with a K content of 56% higher than KCl which has a range of 52%. Another advantage of K_2CO_3 is the presence of elements of C and O. The effect of increasing K is also given by guano because guano is an organic fertilizer that contains K.

Table 3. Soil potential K.

Treatments	Potential K (mg 100 g^{-1})[a]
A	8.53 a
B	21.30 cd
C	24.31 d
D	7.76 a
E	23.27 d
F	13.04 ab
G	14.26 b
H	25.69 d
I	17.96 bc

Note: [a] The average number in the column marked with the same letter shows no significant difference according to Duncan's Multiple Range Test at the 5% level.

Potassium (K) is a macronutrient that is essential for plant growth and development. Potassium has a role as an activator of several enzymes in plant metabolism. Potassium plays a role in the synthesis of protein and carbohydrates, and increases the translocation of photosynthate to all parts of the plant

[5]. Besides, potassium can also maintain cell turgor pressure and water content in plants, increase plant resistance to disease and drought, and improve crop yields and quality [9].

3.4. Soil reaction (pH)

Based on statistical data, there was not significantly difference between treatment with or without Guano and K_2CO_3 to soil reaction (pH) value. In general, the pH value increased when compared to the soil analysis before the experiment. The pH value at soil analysis before the experiment was 6.05 with slightly acidic criteria. Increasing pH was not significantly affected during the experiment due to the buffer properties of the soil. A buffer solution is a soil property that functions to maintain pH even if a little acid, base or dilution is added. Therefore, it is understandable why all treatments given either guano or K_2CO_3 cannot increase the pH value drastically during the experiment. Based on the soil pH criteria, the pH value in each treatment A, B, D, F, G, H, and I is still in the slightly acidic criteria (5.5 to 6.5) while in treatment E (2.93 g urea + 0.84 g K_2CO_3 + 5.42 g guano) the criteria for the pH value are neutral category (6.6 to 7.5).

The increase of pH due to fertilizer's addition causes a reaction between phosphate with ions that cause soil acidity such as Al. Aluminum would inactive and replaces hydroxyl ions then releases these ions into the soil solution so that the pH increases. Besides, the effect of organic compounds derived from guano fertilizers can react with Al cations to form Al chelate compounds as a contributor to H^+ ions which cause soil acidity, so that it can reduce Al solubility and pH can increase with the provision of organic matter [10].

Table 4. Soil reaction (pH).

Treatments	pH [a]
A	6.39 a
B	6.37 a
C	6.49 a
D	6.46 a
E	6.70 a
F	6.39 a
G	6.45 a
H	6.50 a
I	6.38 a

Note: [a] The average number in the column marked with the same letter shows no significant difference according to Duncan's Multiple Range Test at the 5% level.

3.5. Number of tuber per plant

Table 5 showed no significant difference in the number of tubers. Both control and all treatments provide the same value. This is presumably because the nutrient content in the soil before the experiment was relatively high, therefore all the treatments did not give a significant difference to the number of tubers per plant.

Tabel 5. Number of tuber per plant.

Treatments	Number of tuber[a]
A	4.72 a
B	5.22 a
C	4.22 a
D	3.72 a
E	5.11 a
F	4.61 a
G	4.72 a
H	5.50 a
I	4.28 a

Note: [a] The average number in the column marked with the same letter shows no significant difference according to Duncan's Multiple Range Test at the 5% level.

4. Conclusions

The application of K_2CO_3 and guano could increase soil potential P and potential K. However, this value is not significantly different from standard NPK treatment. The soil reaction (pH) shows the same value between all treatments. Thus K_2CO_3 and guano can provide an equivalent value to standard fertilizer application or has the potential to be used as fertilizer.

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