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RESEARCH ARTICLE

STUDYING THE RESIDUAL EFFECT OF ZEOLITE AND MANURE ON ALFISOLS CATION EXCHANGE CAPACITY AND GREEN BEAN YIELD

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ABSTRACT

Nowadays the innovations in organic agriculture systems continue to be developed to achieve a sustainable agriculture system. In Indonesia with high rainfall, nutrient loss is still a major problem. The application of zeolite and manure as a soil amendment is expected to increase nutrients available in soil and cation exchange capacity of the soil in the long term. The results on the first planting season showed a significant increase in chemical soil fertility. The objective of this study is to research the effect of residue zeolite and manure on soil chemical fertility and yields of the second planting season. This study used a complete randomized block design. The factors were a dose of zeolite (Z1: 2.5 tons ha $^{-1}$; Z2: 5 tons ha^{-1}) and kind of manure (P1: quail manure; P2: cow manure), with three replications. The result showed that zeolite treatment of 5 tons ha^{-1} and cow manure increased the total N soil by 27.78% and 45.4% compared to the control. The treatment of quail manure increased soil organic matter 78.78% compared to the control. The treatment of cow manure increased the green bean yield 28.76% compared to the control.

Keywords: Alfisol, Cation Exchange Capacity, Manure, Residue, Zeolite

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INTRODUCTION

Land degradation is a major problem in the agriculture sector, such as the occurrence of soil compaction, metal-polluted, and loss of soil organic matter content (Bouma, Keesstra, & Cerdà, 2017). Land degradation has been defined as any loss of soil quality, productivity, and ecosystem service (Lambin, Geist, & Lepers, 2003). A conventional farming system with excessive land processing can accelerate the loss of soil organic matter impacting the ability of nutrient-binding soils to decrease (Mumpuni, 2016). Studies utilizing zeolite and manure in polluted by metal showed that zeolite can restore a friendly to biota soil environment, reduce the mobility of Cd and Pb, and recover plant performance (Misaelides, 2011).

The natural zeolite is a crystalline aluminosilicate whose composition is similar to clay minerals. Zeolite has useful physical and chemical properties such as ion exchange, molecular sifting, catalysis, and absorption (Chowdhury et al., 2016). The zeolite composition consists of 70-75% Clinoptilolite, 10% Cristobalite, 5-10% Amorphous minerals,

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and below 5% includes sanidine, calcite, and dolomite (Nikolov, Rostovsky, & Nugteren, 2017). Cations on zeolites are bound by weak bonds and can be easily replaced without changing their aluminosilicate structure (Jaskunas, Subačius, & Šlinkšiene, 2015). The nature of zeolite can bind nutrients and store them so that they are not washed away but are absorbed by plants little by little (Eprikashvili et al., 2016), and that land productivity can increase.

The manure is an organic fertilizer from animal waste. The contains of manure are macronutrients such as Nitrogen (N), Phosphate (P), and Potassium and micronutrients such as Calcium (Ca), Magnesium (Mg), and Manganese (Mn) (Andayani & Sarido, 2013). The addition of manure is expected to be a source of macro and micronutrients, increasing the cation exchange capacity (CEC) of the soil, and forming complex compounds with metal ions such as Al, Fe, and Mn to avoid poisoning (Faissal et al., 2017).

The result of the study in the first planting season showed that zeolite and manure could increase CEC by 161.12% compared to the control. The purpose of this study is to research the effect of residue zeolite and the kind of manure on Alfisols chemical fertility especially cation exchange capacity in the second planting season. The gap of the first planting season with the second planting season is 1 month. All treatments were carried out during the first planting season and were not given any additional input during the second planting season.

MATERIALS AND METHOD

This study was conducted as Karanganyar Regency Central Java. The soil used in this study is Alfisols in accordance with the USDA (United States Department of Agriculture) soil classification. The climate of this study field is a tropical and coincided with the rainy season. The first planting season was conducted from June to September 2016 and the second planting season was conducted from November 2016 to February 2017.

Table 1. Characteristics of initial soil in the first planting season, zeolite and manure

Chemical Characteristics	Soil	Manure		Zeolite
		Quail	Cow	
pH H_2O	5.40	-	-	-
C-organic (g kg^{-1})	1.15	17.56	19.94	-
Soil Organic Matter (g kg^{-1})	1.93	24.90	28.30	-
CEC (cmol kg^{-1})	18.93	-	-	78.20
Base Saturation (g kg^{-1})	14.32	-	-	-
C/N Ratio	4.42	13.31	14.30	-
N Total (g kg^{-1})	0.26	1.32	1.40	-
P Availability (mg kg^{-1})	4.45	4.54	4.41	-
K Availability (cmol kg^{-1})	0.22	1.51	1.40	-
Ca (cmol kg^{-1})	1.72	-	-	-
Mg (cmol kg^{-1})	0.56	-	-	-
Na (cmol kg^{-1})	0.20	-	-	-

Source: Laboratory analysis

Table 2. Combination of doses of zeolite and manure treatment

Zeolite Doses	Types of Organic Fertilizer		
	Control	Quail Manure (5 tons ha^{-1})	Cow Manure (5 tons ha^{-1})
Control	Z_0P_0	Z_0P_1	Z_0P_2
2.5 tons ha^{-1}	Z_1P_0	Z_1P_1	Z_1P_1
5 tons ha^{-1}	Z_2P_0	Z_2P_1	Z_2P_2

Table 3. Characteristics of initial soil in the second planting season

No	Treatment	pH H_2O	CEC (cmol kg^{-1})	Base saturation (g kg^{-1})	Soil Organic Matter (g kg^{-1})	N-Total (g kg^{-1})	P Available (mg kg^{-1})	K Available (cmol kg^{-1})
1	Z0P0	6.27	23.56	42.41	1.292	0.530	4.54	0.32
2	Z0P1	6.45	46.74	57.32	1.482	0.683	4.61	0.37
3	Z0P2	6.42	47.44	58.62	1.732	0.555	4.73	0.38
4	Z1P0	6.13	48.49	46.17	1.417	0.620	4.68	0.33
5	Z1P1	6.33	49.78	57.97	1.876	0.671	4.74	0.41
6	Z1P2	6.07	51.24	61.14	1.897	0.772	4.80	0.45
7	Z2P0	6.10	52.48	62.22	1.749	0.695	4.78	0.39
8	Z2P1	6.03	46.49	62.92	1.841	0.724	4.88	0.44
9	Z2P2	6.11	49.16	67.33	1.997	0.781	4.92	0.49

Source : Laboratory analysis

Materials

The green bean variety used in this study is local varieties. The zeolite used in this study was collected from Klaten Regency in Central Java. Particle size in this zeolite varied between 2-4 mm. The All of kind manure used in this study was collected from Karanganyar Regency in Central Java Zeolite and manure in each treatment applied to the plot on first planting season and no additional input was given during the second planting season. Chemical characteristics of initial soil in the first planting season, zeolite and manure are shown in Table 1. Characteristics of initial soil in the second planting season are shown in Table 3.

Method

This study used a complete randomized block design. The factors were a dose of zeolite (Z1: 2.5 tons ha $^{-1}$; Z2: 5 tons ha^{-1}) and kind of manure (P1: quail manure; P2: cow manure), with three replications (Table 2). This study method followed the soil testing method improvement in the Indonesian Minister of Agriculture Regulation Number 70 of 2011 (Kementan, 2011)

The implementation of this study included land preparation, plant preparation, planting, maintenance, and harvesting. Land preparation was carried out by scrubbing each of the plots that have been formed in the first planting season and by clearing the weeds. The plots dimension is 2 x 1 m with 30 cm spacing between plots. Plant preparation was done by selecting local varieties of green beans that were not defective and not contaminated with disease. Plant spacing in each plot was 20 x 25 cm, 80 seeds sown in each plot (Rukmana, 1997) and thinned to 40 plants per plot. Maintenance was done by watering, weeding, and pest controlling. Harvesting was done when the green bean pods started to become brown and dry out. Plant sampling is taken at harvest, 3 plants per plot were taken as samples. Soil sampling is taken at initial and harvest. Soil samples were collected from each plot (1.5 kg) and mixed to get a composite sample.

The post-harvest soil samples were air-dried at room temperature before analysis. The Laboratory analysis method accord to the Technical Guidelines for Analysis of Soil, Plant, Water and Fertilizer Chemistry, Bogor Soil Research Center (Eviati & Sulaeman, 2009). Analysis of pH was done using the pH meter method with a ratio of 1:2.5 (soil: distilled water) (Day, 1965). Analysis of cation exchange capacity used a method of saturating ammonium acetate at neutral pH (Allison et al., 1954). Analysis of N total used the Kjeldahl method (Jackson, 1958). Analysis Organic matter used the Walkley & Black (1934) method (Nelson & Sommers, 1982) and the analysis of yield with weighing yields. Data were analyzed using variance analysis or ANOVA, Least Significant Differences (LSD) and Duncan Multiple Range Test (DMRT) with a confidence interval of 95%, and correlation test.

RESULT

Soil pH

The result of soil pH analysis on zeolite residue and manure treatment did not have significant differences in each treatment compared to the control (Z1 $LSD_{0.05}$ = 0.981; Z2 $LSD_{0.05}$ =0.954; P1 $LSD_{0.05}$ = 0.926; P2 $LSD_{0.05}$ = 0.981). The pH value decreased from the first planting season which was 6.03-6.45 to 5.11-5.15.

N total of the soil

The result of variance analysis shows that treatment zeolite 5 tons ha^{-1} and cow manure had a significant effect on the N total soil compared to the control (Z2 $LSD_{0.05}$ = 0.015; P2 $LSD_{0.05}$ =0.001). Whereas treatment 2.5 ha^{-1} and quail manure had a non-significant effect (Z1 $LSD_{0.05}$ = 0.524; P1 $LSD_{0.05}$ =0.088).

The highest total N increase was obtained by giving zeolite 5 tons ha^{-1} (Figure 1). The addition of zeolite increased the total N of soil to 0.46% (medium) or increased with the percentage increase of 27.78% compared to the control.

The highest total N increase in soil was obtained by giving cow manure (Figure 2). The addition of manure increased the total N of soil to 0.48% (medium) or increased with the percentage increase of 45.4% compared to the control

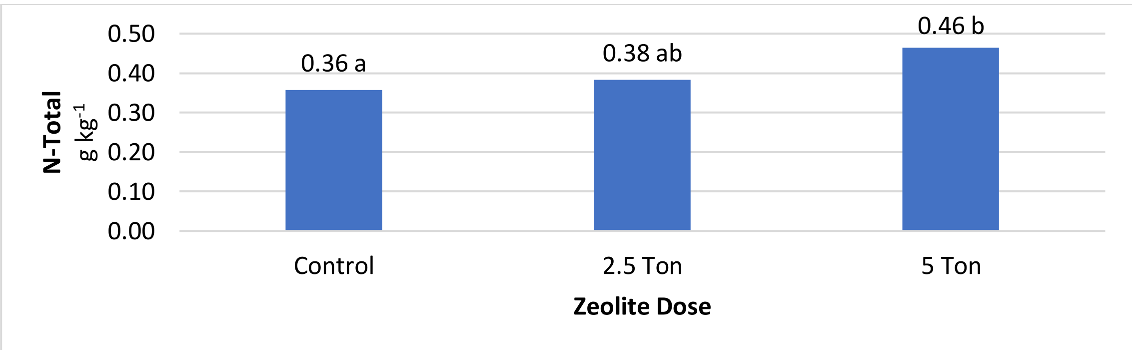

Figure 1. The total N content of the soil due to residue from various doses of zeolite. Note: The numbers followed by the same letters show no significant difference at the level of 0.05 with DMRT

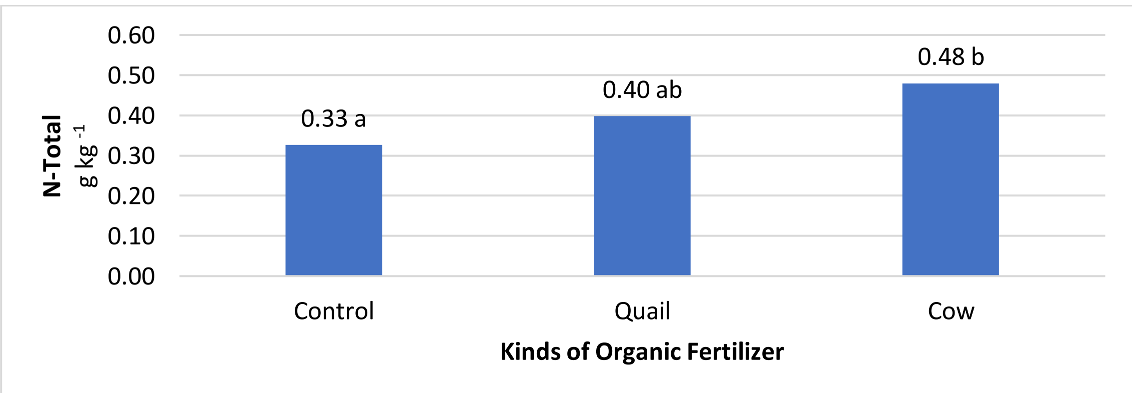

Figure 2. The total N content of the soil due to the residue kind of organic fertilizer. Note: The numbers followed by the same letters show no significant difference at the level of 0.05 with DMRT

Table 4. Soil organic matter in the first planting season and second planting season

No	Treatment	First planting season (%)	Second planting season (%)
1	Z0P0	1.292	0.481
2	Z0P1	1.482	1.104
3	Z0P2	1.732	1.022
4	Z1P0	1.417	0.713
5	Z1P1	1.876	1.135
6	Z1P2	1.897	0.930
7	Z2P0	1.749	0.784
8	Z2P1	1.841	1.291
9	Z2P2	1.997	1.220

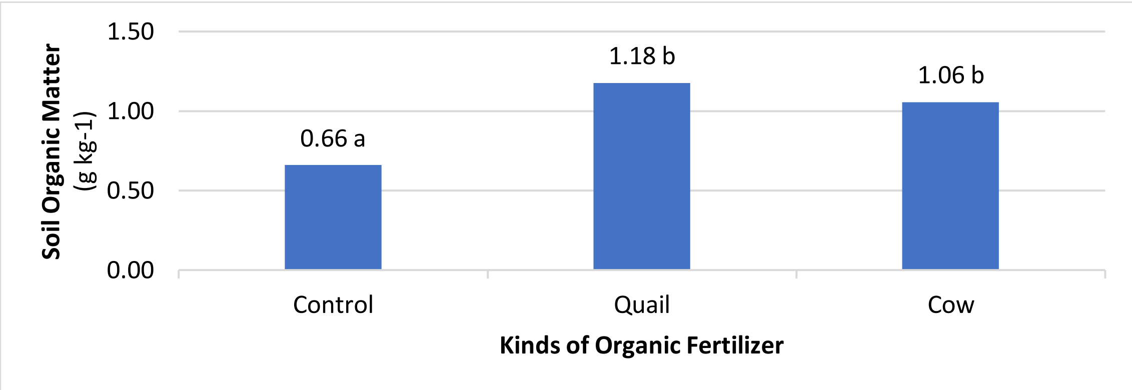

Figure 3. The content of soil organic matter due to the residue of providing various kinds of manure. Note: The numbers followed by the same letters show no significant difference at the level of 0.05 with DMRT

Soil organic matter

The soil organic matter experienced a decrease from the first planting season (Figure 3). The result of variance analysis shows that each addition of manure significantly affected to the increase soil organic matter in the second planting season compared to the control (P1 $LSD_{0.05}$ =0.009; P2 $LSD_{0.05}$ =0.038). Whereas the treatment of doses of zeolite had a non-significant compared to the control (Z1 $LSD_{0.05}$ =0.752; Z2 $LSD_{0.05}$ = 0.213). The highest increase in soil organic matter level was obtained by giving quail manure 5 tons ha^{-1} which was 1.18% (low) with an increasing percentage of 78.78% compared to the control (Figure 3).

CEC soil

Cation exchange capacity is an important thing that can affect plant nutrient availability. The result of the analysis of the variety of CEC soil on the residue of dose zeolite and kind manure treatment did not have significant differences in each treatment compared to the control (Z1 $LSD_{0.05}$ =0.329; Z2 $LSD_{0.05}$ = 0.074; P1 $LSD_{0.05}$ =0.429; P2 $LSD_{0.05}$ = 0.471). However, even though it did not have a significant difference, residues of dose zeolite and kind manure could still increase the CEC value compared to control (Figure 4). The CEC rate decreased from 23.56 cmol kg^{-1} – 52.48 cmol kg^{-1} (high – very high) to 23.79 cmol kg^{-1} – 31,974 cmol kg^{-1} (high) (Figure 4).

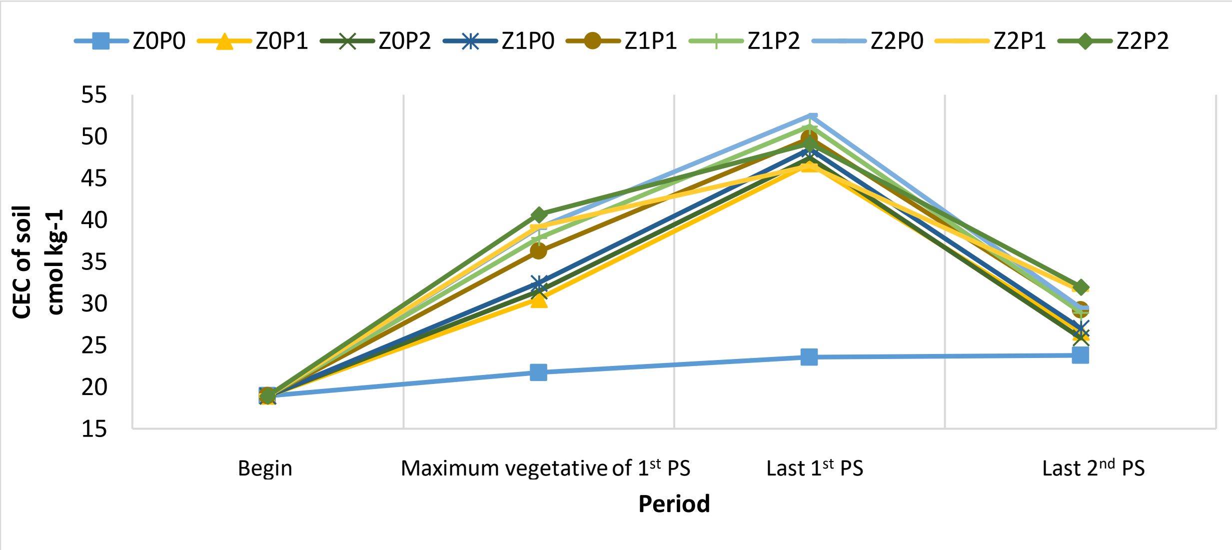

Figure 4. Graph of the total CEC soil in each treatment. Note: PS= Planting Season

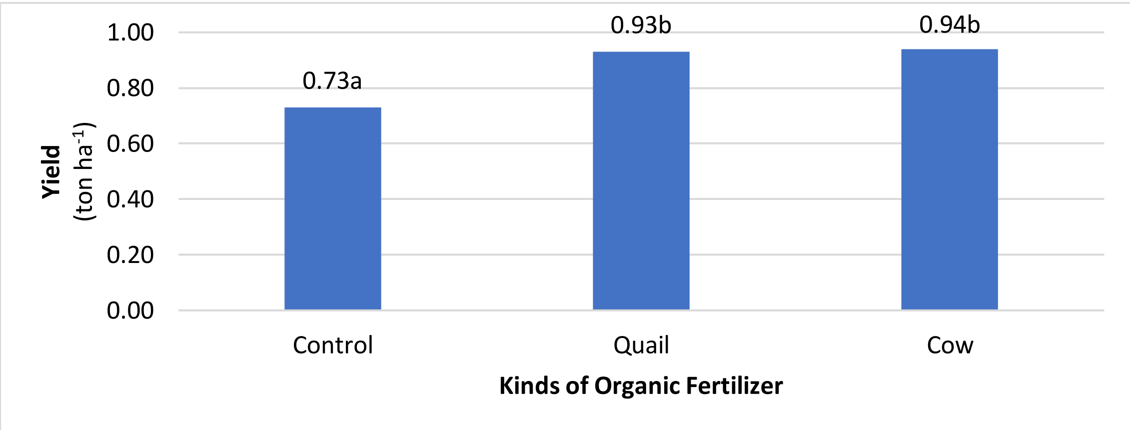

Figure 5. The green bean yield due to residue of giving kind manure. Note: the numbers followed by the same letters show no significant difference at the level of 0.05 with DMRT

Green Bean Yield

The yield of variance analysis shows that the additional kinds of manure had a significant effect on increasing the yield in the second planting season compared to the control (P1 $LSD_{0.05}$ = 0.000; P2 $LSD_{0.05}$ =0.000). Whereas zeolite treatment had a non-significant effect compared to the control (Z1 $LSD_{0.05}$ =0.910; Z2 $LSD_{0.05}$ =0.287).

The highest yield of the green bean was obtained from the treatment of cow manure, which was 0.94 tons ha^{-1} with an increase of 28.76% compared to the control (Figure 5).

DISCUSSION

Correlation of N total and soil organic material

The addition of zeolite could still increase N total soil in the second planting season. The binding process of NH_4^+ to the negative charge of zeolite which was then released slowly by zeolite minerals could control the nitrification process so that it could prevent the occurrence of N loss in the soil (Latifah, Ahmed, & Majid, 2017). According to Al-Jabri (2010), the nutrients absorbed in zeolite pores will be released slowly even in the next planting season. The amount of N-total increase is directly proportional to the amount of zeolite added.

The addition of manure could significantly increase the total soil N in the second planting season. Manure residues can increase the total N (Harieni & Minardi, 2013) and contains organic material on manure that will undergo mineralization and provide N elements available on the soil (Nyamasoka et al., 2017). Organic materials found in manure will be a buffer on the soil so that soil pH would not be easily changed. Recent research said that buffer solutions in the soil can reduce the activity of nitrifier bacteria on the soil so that N elements in the soil are not easily lost (Li, Chapman, Nicol, & Yao, 2018). Nitrification control is important to prevent N loss to soil (such as due to denitrification and leaching) so that the use of N by plants will increase (Chen et al., 2015).

The total N increase in cow manure treatment was higher than the treatment of quail manure (Figure 2) because the total N in cow manure was higher at 1.40% compared to the total N in quail manure which was 1.32%. The result of another study revealed that the supply of N from cow feces has the potential to increase total N of land (Powell et al., 2017).

The treatment of quail manure increase soil organic matter 78.78% compared to the control. The addition of manure has the potential to maintain the stability of soil organic matter in the long term (Powell et al., 2017). Based on the results of the correlation test, the soil organic matter is correlated with total N soil (r = 0.22). The more organic matter in the soil, the more N will be. Other research says fertilization with manure will increase soil organic matter which will experience mineralization slowly so that it can increase soil chemical fertility in the long term (Zhe E et al., 2012).

Cation exchange capacity

The cation exchange capacity experienced a decrease from the first planting season (Figure 4). But the decrease was still at a high CEC level (23.79 cmol kg^{-1} – 31,974 cmol kg^{-1}). High CEC value even after harvesting the second planting season was due to the nature of zeolite which could act as ion exchange sites and had a high inherent exchange capacity (Chowdhury et al., 2016; Gholamhoseini et al., 2013). The addition of zeolite and manure could increase CEC in the following year (Gholamhoseini et al., 2013). The application of manure would increase CEC by releasing compounds such as lignin which can absorb cations and add humus to the soil so that CEC will increase (Lima et al., 2009).

CEC value is strongly influenced by colloidal minerals and soil organic matter (Ulery, Graham, Goforth, & Hubbert, 2017). In addition, the pH value also greatly affects the total CEC; the more acidic the pH value, the smaller the CEC value (Siemion, Lawrence, & Murdoch, 2014). At acidic pH, the concentration of high H^+ ions and OH^- ions thus increased AEC (Anion Exchange Capacity) and decreased CEC (McHale, Burns, Siemion, & Antidormi, 2017). The decrease in pH and soil organic matter on the second planting season caused a decrease in the value of CEC soil. The high rainfall during the study increased the speed of leaching of zeolites and organic fertilizers on the soil (Meite et al., 2018) and cause more acidic soils (Francos, Pereira, Alcañiz, Mataix-Solera, & Úbeda, 2016). Changes in the nature of the soil to acid were also influenced by microbial activity such as nitrification (Latifah et al., 2017). University of Sebelas Maret Climatology Station noted that during the experiment there were 11 extreme rains, namely on November 10th, 2016 (63 mm), November 12th, 2016 (82 mm), November 14th (51 mm), October 2nd, 2016 (63 mm), January 12th, 2017 (71 mm), February 2nd, 2017 (59 mm), February 9th, 2017 (53 mm), and February 21st, 2017 (142 mm). Based on the result of the correlation analysis, it was known that CEC was correlated with base saturation (r = 0.742). The higher the CEC, the base saturation will also be higher. Zeolite material binds plant nutrients (K, Ca, Mg, Na) (Manolov, Antonov, Stoilov, Tsareva, & Baev, 2005).

Green bean yield

On the other hand, the treatment of 5 tons ha^{-1} of cow manure increase green bean yield 28.76% compared to the control. The addition of manure can increase the nutrient content of the soil, especially N and P, so that nutrient supply for plants is more abundant and followed by an increase in production (Faissal et al., 2017). The result of the correlation test showed a correlation between the yield and N total (r = 0.461) so that the higher the N nutrients in the soil, the higher the green bean plants. Nitrogen is a macronutrient needed for plant growth. The nitrogen absorbed by plants will be reduced to ammonia and eventually become a variety of proteins for plant growth (Xin et al., 2014).

CONCLUSION

Chemical soil fertility in the second planting season has decreased. The CEC did not a significant difference in each treatment but was still higher than the control. The highest CEC value was 31.97 cmol kg^{-1} (high) which was in the Z2P2 treatment or increase 34.4% compared to the control. The biggest green bean yield was obtained from cow manure treatment which was 0.94 tons ha^{-1} or increases 28.76% compared to the control.

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