The utilizing of zeolite and manures for increasing potassium availability, uptake, and yield on soybean in Alfisols

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Abstract. Enhancement soybean production is needed to fulfill its high demand in Indonesia by utilizing the widespread potential land, such as Alfisols. Zeolite and manure addition used to overcome the nutrient availability in Alfisols and decrease the use of inorganic fertilizer. This study was conducted in field condition in a factorial randomized complete block design with three replicates in an Alfisols aimed to assess the effect of applying three rates of zeolites (Z0: 0 t.ha−1, Z1: 2.5 t.ha−1 and Z2: 5 t.ha−1) and three types of 5 t.ha−1 manures (P0: 0 No Manure, P1: quail manure (5 t.ha−1), P2: cattle manure (5 t.ha−1)) on K availability, its uptake, number of pods and seed weight/plot on soybean [Glycine max. (L) Merrill]. Zeolites showed a significant result of potassium availability at the rate 5 t.ha−1. The similar result is given by cattle manure for potassium uptake in soybean. An interaction between zeolites at the rate 5 t.ha−1 and cattle manure showed the significant result on a number of pods/plant−1, 100-seeds weight and seed yield.

1. Introduction
Soybean has a great role as a staple food in Indonesia, important for cropping system moreover as a feeder. According to statistics Indonesia merely able to fulfill one-third of their needs, which is about 7.8 tons and imported about 1.8 tons that year [1]. An enhancement is needed to fulfill high demand of soybean but still eco-friendly. Utilizing widespread potential land such as Alfisols is one effort that can be done.

Alfisols with an area of 7 hectares scattered in Java and West Nusa Tenggara. Alfisols are known to have undergone moderate leaching, are susceptible to surface compaction, erosion and acidify rapidly under continuous cultivation. They have low water retention capacity and are tend to be deficient in macronutrient [2],[3]. Alfisols formed by crust and seal process on the soil surface, resulting very low infiltration even under dry soil condition [4]. Alfisols inert mineral composition and its lack of interparticle bonding leads to low organic matter content. Unstable soil aggregation together with a conventional system of farming increase the potential for soil surface sealing and crusting [5]. Nitrogen (N), Phosphorus (P), and potassium (K) have great effects on plant growth and development. Deficiencies or excesses of N, P, K resulting marked effects on the growth and yield of crops. Potassium as a macronutrient required for regulation of metabolic system in plants, therefore its availability needs...
to be improved to increase grain yield. Therefore, productivity is significantly affecteded nutrient deficiency [6],[7].

Potassium availability can be improved by zeolite addition which prevents nutrient leaching with its ability to absorb K cation. Zeolites are crystalline hydrated aluminosilicates of alkali and alkaline earth cations [8]. Zeolites when dehydrated develop a porous structure made up of Si-O and Al-O tetrahedrons, which bond together sharing vertices and forming a square and hexagonal structures. Zeolites have an important role in improving the soil fertility and in the prevention of nutrition losses [9],[10]. Cattle and quail manure selected as fertilizer to provide nutrient for soils. Manure application improves physical and chemical properties of soil, in addition, increases microorganism activity and water retention capacity. Nutrient availability and soil structure improved by application of manure and usually increased crop yield [11]. Zeolite and manure combination expected to prevent leaching and provide nutrient continuously to overcome problems in Alfisols.

The present study aimed to assess the effects of the use of two zeolite rates (2.5 t.ha\(^{-1}\) and 5 t.ha\(^{-1}\)) and two types of manure (quail manure and cattle manure) on the Potassium availability and uptake on soybean its yield adapted to Alfisols.

2. Materials and Methods
This study was conducted in field condition at Sebelas Maret University experimental field, located in Jumantono district, Karanganyar Regency, Central Java, Indonesia at the geographical coordinates of 7° 37’ 49.9’’ S and 110° 56’ 54.4’’ W. The soil from this study area is Alfisols according to the USDA (United States Department of Agriculture) soil classification.

The soybean variety used in this study is “Gema”, crossing result of Shirome and Wilis variety. Three blocks prepared with 30 cm spacing between block, each block contains 9 plot (2x1 m) with 30 cm spacing between plot. Plant spacing in each plot was 20 x 25 cm, 120 seeds sown in each plot and thinned to 40 plants per plot. The watering was estimated visually as the soil surface dried.

This study was arranged in a factorial randomized complete block design with 3 x 3 factorial three rates of zeolites (Z0: 0 t.ha\(^{-1}\), Z1: 2.5 t.ha\(^{-1}\) and Z2: 5 t.ha\(^{-1}\)) and three types of manures (P0:0 No Manure, P1: quail manure (5 t.ha\(^{-1}\)), P2: cattle manure (5 t.ha\(^{-1}\)) with three replicates. The zeolite used in this study was collected from Klaten Regency in Central Java. Particle size in this zeolite varied between 2-4 mm. Zeolite and manure in each treatment applied to the plot 5 days before seeds were planted. Before the treatment applied, initial soil samples were collected from each plots and mixed together to get a composite sample. Chemical characteristics of the initial soil, zeolite, and manure are shown in Table 1.

### Table 1. Chemical characteristics of experimental plot soil, manure, and zeolite

| Chemical Characteristics | Soil | Manure | Zeolite |
|--------------------------|------|--------|--------|
| pH H\(_2\)O               | 5.4  | -      | -      |
| C-organic (g.kg\(^{-1}\)) | 1.15 | 17.56  | 19.94  |
| Soil Organic Matter (g.kg\(^{-1}\)) | 1.93 | 24.9   | 28.3   |
| 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 | -      | -      |

Plant sampling for potassium uptake was taken when the flower starts to bloom. Each plant dried in forced circulation oven at 70°C and subsequently ground for K uptake determination. Whole plants of
each plot were harvested for yield determination. After harvesting the soybean, soil samples were collected from each plot.

The post-harvest soil samples were air dried at room temperature before analysis. The soil pH determined by glass electrode pH meter [12]. Soil organic matter quantified by Walkley-Back method [13]. Base saturation (exchangeable K) estimated with ammonium acetate extraction method [12]. The dried plant tissues ground and digested with concentrated HNO₃ [14], for determination of K using a flame photometer. The results were subjected to analysis of variance (ANOVA), and means compared using Duncan’s Multi Range Test DMRT with SPSS ver 23.0 (SPSS, Inc., Chicago, IL, USA).

3. Results and Discussion

Soil pH showed no significant difference between treatment but a slightly enhancement in every treatment compared with control. The highest pH given by zeolite 5 t.ha⁻¹ and cattle manure while the lowest pH given by control with 5.7. Polat et al. [15] stated that zeolite is not acidic but marginally alkaline and its use with fertilizers can help buffer soil pH levels, thus reducing the need for lime application.

Soil base saturation describes how completely the soil particle surface is filled with the basic cations such as K, Ca, Mg, Na [15]. The base saturation showed no significant difference between treatment. Highest result given by zeolite 5t.ha⁻¹ and cattle manure, increasing 59% compared with control.

The potassium availability in soil varied due to the different rates of zeolite and manure types application. The findings responded differently to zeolite, with increase 11% and 22% in potassium availability with zeolite rates 0 t.ha⁻¹ to 2 t.ha⁻¹ and 5 t.ha⁻¹ respectively (Table 2). Regarding manure types, cattle manure showed the higher result compared with quail manure in each zeolite rate. Potassium often limits production and needs to be included in a soil fertility program; potassium should be included as a corrective nutrient [17]. Application of zeolite in combination with organic fertilizer had also shown impact in terms of potassium availability. This result comparable to that reported by Basri et al. [18].

| Treatments | pH | Base Saturation (%) | Availability K (cmol.kg⁻¹) | K Uptake (mg/plant) |
|------------|----|---------------------|-----------------------------|---------------------|
| Z0P0       | 5.70 | 42.41               | 0.32                        | 138.12              |
| Z0P1       | 5.83 | 57.32               | 0.37                        | 223.58              |
| Z0P2       | 5.77 | 58.62               | 0.38                        | 286.51              |
| Z1P0       | 5.73 | 46.17               | 0.33                        | 175.15              |
| Z1P1       | 5.80 | 57.97               | 0.41                        | 279.73              |
| Z1P2       | 5.80 | 61.14               | 0.45                        | 309.20              |
| Z2P0       | 5.90 | 62.22               | 0.39                        | 170.82              |
| Z2P1       | 6.00 | 62.92               | 0.44                        | 345.71              |
| Z2P2       | 6.10 | 67.33               | 0.49                        | 373.57              |

Description: Z0P0: control, Z0P1: quail manure 5 t.ha⁻¹, Z0P2: cattle manure 5 t.ha⁻¹, Z1P0: zeolites 2.5 t.ha⁻¹, Z1P1: zeolites 2.5 t.ha⁻¹+quail manure 5 t.ha⁻¹, Z1P2: zeolites 2.5 t.ha⁻¹+cattle manure 5 t.ha⁻¹, Z2P0: zeolites 5 t.ha⁻¹, Z2P1: zeolites 5 t.ha⁻¹+quail manure 5 t.ha⁻¹, Z2P2: zeolites 5 t.ha⁻¹+cattle manure 5 t.ha⁻¹.

The present study showed that cattle manure give the higher result for potassium uptake on soybean in each zeolite rate (Table 2). Quail manure and cattle manure increased potassium uptake 17% and 27% compares to without manure treatment respectively (Table 2). Moreira et al. [6] also reported that potassium concentration in the plants increased significantly with increasing potassium rates. The fertility treatment significantly increased accumulation of potassium uptake. These findings suggest that supplemental fertilization in this study was used as a strategy to maintain greater nutrient availability, leading to increased nutrient uptake, and ultimately grain yield. Increased nutrient accumulation did not always lead to greater nutrient removal [19].
Table 3. Effect of treatment to height, dry weight, number of pods, 100 seeds weight and seed yield of soybean

| Treatments | Height (cm) | Dry Weight (g) | No. of Pods (pods.plant⁻¹) | 100-seeds Weight (g) | Seed Yield (t.ha⁻¹) |
|------------|-------------|----------------|-----------------------------|----------------------|---------------------|
| Z0P0       | 7.5         | 12.1           | 23.1                        | 15.68                | 56 a                | 1.13 a            |
| Z0P1       | 10.3        | 15.2           | 24.5                        | 16.07                | 61 c                | 1.28 b            |
| Z0P2       | 10.4        | 15.6           | 27.2                        | 17.66                | 74 d                | 1.34 c            |
| Z1P0       | 9.7         | 15.6           | 27.6                        | 18.33                | 58 b                | 1.28 b            |
| Z1P1       | 10.7        | 15.6           | 27.7                        | 18.74                | 61 c                | 1.34 c            |
| Z1P2       | 10.0        | 16.0           | 26.7                        | 18.53                | 74 d                | 1.43 d            |
| Z2P0       | 9.3         | 15.5           | 27.1                        | 17.77                | 60 c                | 1.30 b            |
| Z2P1       | 10.3        | 16.3           | 29.3                        | 19.63                | 74 d                | 1.34 c            |
| Z2P2       | 10.2        | 16.9           | 29.7                        | 20.26                | 101 e               | 1.52 e            |

The number followed by the same letters on the same row are not significantly different according to Duncan Multiple Range Test (DMRT) at 5% level.

Plant height showed slightly enhancement but no significant difference between treatments in every week (Table 3). The shortest plant height at 4th week was 23.1 cm given by control; the highest one was 29.7 cm, given by zeolite 5 t.ha⁻¹ and cattle manure [17].

The dry weight result showed no significant difference but slightly enhancement in every treatment. Zeolite 5 t.ha⁻¹ combined with cattle manure increase 29% of dry weight compared to control. Soybean 100-seeds weight showed significant differences between each manure type treatment. The highest result is given by zeolite 5 t.ha⁻¹ and cattle manure, increasing 35% compared with control.

The number of pods.plant⁻¹ was the highest with 5 t.ha⁻¹ of zeolites and cattle manure, which was significantly highest than other treatments. The maximum number of pods.plant⁻¹ was recorded from treatments with highest potassium availability (Table 2). Parvej et al. [20] showed the same result. The result is in agreement with the findings of Xiang et al. [21] who reported that the number of pods.plant⁻¹ was influenced significantly by potassium rates.

The highest soybean yield (2.90 t.ha⁻¹) given by zeolite 5 t.ha⁻¹ and cattle manure (Table 3). The maximum result was recorded from treatments with highest potassium availability (Table 2). The result was in agreement who also reported a similar finding on seed yield of soybean under the condition of the proper potassium rate [22]. The lowest seed yield was recorded from 0 t.ha⁻¹ zeolite and without manure that might due to the lowest performance yield attributes under the same treatment. Increases in soybean yield were obtained in response to K fertilization [17].

Table 4. Correlation between soil characteristic, soybean growth, and yield

| pH | No. of Pods | Seed Yield | K Uptake | Base Saturation | Dry Weight | 100-seeds Weight | K Availability |
|----|-------------|------------|----------|-----------------|------------|------------------|---------------|
| 1  | .582**     | .475**     | .342     | .561**          | .251       | .515**           | .425*         |
| No. of Pods | 1 | .800**     | .646**   | .526**          | .144       | .848**           | .643**        |
| Seed Yield  | .475**   | .800**     | 1        | .754**          | .210       | .824**           | .718**        |
| K Uptake  | .342     | .646**     | .754**   | 1               | .592**     | .004             | .614**        |
| Base Saturation | .561**   | .526**     | .540**   | .592**          | 1          | .058             | .590**        |
| Dry Weight | .251     | .144       | .210     | -.004           | .226       | .195             | .699**        |
| 100-seeds weight | .515**   | .848**     | .824**   | .614**          | .226       | 1                | .699**        |
| K Availability | .425*    | .643**     | .718**   | .562**          | .385*      | .195             | 1             |

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).
Dry weight showed a negative correlation between potassium uptake and soil base saturation. The result indicates that a potassium uptake not related to dry weight. Positive and strong correlation of potassium availability, its uptake on soybean and number of pods with grain yield revealed the importance of these characters in determining grain yield. A lot of potassium needed for pod forming and seed replenishment [23]. Seed will be formed inside the pod and continues until it’s fully formed. The role of potassium in agriculture is intimately connected with photosynthesis. The number of pods plant$^{-1}$ and seed yield increased indicated a relation with potassium role in plant photosynthesis [24]. Higher potassium rates increase plant photosynthesis causing a number of pods plant$^{-1}$ and seed yield increased.

4. Conclusion
It may be concluded from the result of this study that the application of Zeolite and manure influenced soil fertility, soybean growth, and yield. A number of pods plant$^{-1}$, 100-seeds weight, and seed yield were significantly affected by zeolite and manure combination. The application of 5 t.ha$^{-1}$ zeolite and cattle manure was found to be the most appropriate combination for maximum productivity of soybean.

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