Zeolite and manure treatment on the increase of N soil, N absorption and soybean production in alfisols

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Abstract. Soybean production in Indonesia could be improved by utilizing Alfisols as potential land. Zeolites and manure are used in this study as slow release materials to reduce nitrogen losses from soil. The aim of this research is reviewing the effect of zeolites and manure in improving N total contents, N absorption, and growth and production of soybean in Alfisols. Factorial randomized complete block designed of two factors (zeolite doses; 0 ton / ha, 2.5 ton / ha, and 5 ton / ha, and type of manure; P0: 0 ton / ha, P1: cow manure, P2: quail manure) were used and field experiments were conducted in this study. Obtained results showing zeolite with dose of 5 ton/ha gave the highest influence indicated by the increase of N total 35.13% and the increase of N absorption up to 53.37%. Cow manure gave the highest efficiency with total N increase of 40.54% and an increase in N absorption of 48.93%. Zeolite 5 ton/ha with cow manure gave the highest yield with an increase of total pod content 129.41%, and the increase of seed weight 35.39 %. Finally, zeolite treatment with cow manure at dose 5 ton/ha is the best treatment in this research.

1. Introduction
A very wide gap can still be found in the production and consumption of soybean in Indonesia. Increase in domestic soybean consumption potentially increase soybean imports, because soybean production has not been able to meet the needs of the community as soybean production in the country tends to decrease [1]. The low production of soybean is caused by the decreasing of fertile land caused by continuous use of inorganic fertilizer [2]. Efforts to increase soybean production in Indonesia to suppress imports are done through intensification, extensification, diversification, and rehabilitation. Extensification efforts are done by utilizing marginal lands, one of them is Alfisols [3].

Alfisols is a soil that experienced intensive weathering and further development, resulting in leaching of nutrients, especially N, P, K. This type of soil generally have low chemical fertility. If the nitrogen element is present in a low state, then the growth and production of the plant will be disrupted [4]. Nitrogen is the most important element for growth and filling of soybean seeds. However, the availability of nitrogen in the soil is generally very low. Whereas the quantity and quality of high soybean seed yield require a high N supply as well.

Manure is a potential source of organic material with its presence available in the environment and it is affordable. Manure is able to increase soil CEC and can form complex compounds with metal ions such as Al, Fe, and Mn so as not to poison its environment [5].
Zeolite as a soil enhancer is a mineral of a hydrogenated aluminosilicate compound with a hollow structure and contains interchangeable alkali cations. The cations in the zeolite are bonded by a weak bond and can be easily replaced without altering the aluminosilicate structure [6]. Zeolite is a natural material that has a high CEC (120-180 meq/100g) and is hollow with a cavity size corresponding to the size of the ammonium ion. This causes the zeolite to absorb the ammonium ion before it turns into nitrate [7].

2. Materials and Methods

This study was carried out on the dry land, Jumantono, located in central Java Indonesia. Laboratory analysis was done in Soil Chemistry and Soil Fertility Laboratory of FP UNS to analysis begins before planting (initial soil), at the time of maximum vegetative and generative.

The research was conducted by using a complete Randomized Complete Block Design factorial with two factors, namely zeolite and manure. The dose of zeolite consists of 3 levels (Z0: 0 t ha⁻¹, Z1: 2.5 t ha⁻¹, and Z2: 5 t ha⁻¹). Type of manure consisting of 3 types, namely (P0: Without Manure, P1: Quail Manure (5 t ha⁻¹), and P2: Cow Manure (5 t ha⁻¹). Each treatment combination was repeated 3 times so that 27 experimental units were obtained. The implementation of the study included plant preparation, land preparation, initial soil sampling, zeolite incubation and manure, planting, maintenance, harvesting (maximum and generative vegetative), and laboratory analysis.

The soil pH was determined in 1:2.5 w/v soil: water mixture. Particle-size distribution was determined by sedimentation method [8], organic carbon concentration by Walkley and Black [9] rapid chromic acid titration, calcium carbonate (CaCO₃) by Bundy and Bremner method [10], cation exchange capacity (CEC) by the neutral normal ammonium acetate method [11]. N (Kjeldahl method) was determined according to Jackson [12] and for analysis crop yield include plant height, fresh weight, dry weight, total pod content, and seed weight. The observed data were analyzed using multiple analysis or ANOVA, Duncan Multiple Range Test (DMRT) and correlation test.

3. Result and Discussion

The soil fertility level in Jumantono area is included in the low category of pH 5.4 (acid), organic c-1.15% (low), 1.93% KTK 18.93 me/100g (medium), KB 14.32% (very low), total N 0.26% (medium), P available 4.45 ppm (very low), K available 0.22 me/100g (Low), Ca 1.72 me/100g, Mg 0.56 me/100g (low), and Na 0.20 me/100g (low). Thus it is necessary to provide manure and zeolite so that plants can grow well and produce a high harvest and profitable.

Table 1. The result of initial soil analysis

| Observation Variable | Result | Unit | Rating |
|----------------------|--------|------|--------|
| pH H₂O               | 5.4    |      | Acid   |
| C-organic            | 1.15   | %    | Low    |
| Organic Material     | 1.93   | %    | Low**  |
| CEC                  | 18.93  | me/100g | Medium |
| Base Saturation      | 14.32  | %    | Low*** |
| Total N              | 0.26   | %    | Medium** |
| P available          | 4.45   | Ppm  | Very low** |
| K available          | 0.22   | me/100g | Very Low |
| Ca                   | 1.72   | me/100g | Very low |
| Mg                   | 0.56   | me/100g | Low |
| Na                   | 0.20   | me/100g | Low |

Description *) : Rating according to FAO (2006) [13]
**): Rating according to Tekalign (1991) [14]
***): Rating according to Landon (1991) [15]
Table 2. Results of analysis of quail manure, cow manure, and zeolite

| Variable   | Quail | Cow | Zeolite | Unit |
|------------|-------|-----|---------|------|
| N total    | 1.32  | 1.40| -       | %    |
| P₂O₅       | 4.54  | 4.41| -       | %    |
| K₂O        | 1.51  | 1.40| -       | %    |
| C-organic  | 17.56 | 19.94| -      |      |
| C/N ratio  | 13.31 | 14.30| -      |      |
| KTK        | -     | -   | 128.20 | me/100g |

C/N ratio of quail manure is 13.31 and C/N of cow manure is 14.30. C/N ratio is high then the nutrient content is slightly available for plants, otherwise, C/N ratio is low then the availability of high nutrients and available for plants [16]. The value of CEC in the zeolite which is 128.20% me/100g CEC (Table 2). Values has met the criteria of technical requirement of the regulation of the ministry of agriculture number 70 with KTK zeolite which is at least 120 me/100g.

Applying zeolite dose of 5 t ha⁻¹ increased pH value by 5.26% compared without applying zeolite. Soil pH increased due to the zeolite undergoes hydrolysis process of silicates which produces OH⁻ ion leading to an increase in soil pH [17]. Application of manure type has no significant effect on soil pH since the organic material has large buffer capacity that if enough soil contains this component, soil pH will be relatively stable [18].

Table 3. Effect of dosing of zeolite on soil pH, N total, and c-organic

| Dose of Zeolite (t ha⁻¹) | pH     | N total (%) | C-organic (%) |
|--------------------------|--------|-------------|---------------|
| 0                        | 5.7a   | 0.37a       | 1.5a          |
| 2.5                      | 5.78a  | 0.45b       | 1.73b         |
| 5                        | 6.0b   | 0.50b       | 1.86b         |

Description: The numbers followed by the same letters show no significant difference in the DMRT test of 5%.

Dose of zeolite and manure type gave a real effect to the increase of total N of soil, while the interaction between them gave no significant effect. Zeolite with a dose of 5 t ha⁻¹ giving the highest total N total value, with increase of 35.13% compared with without zeolite. The increase in total soil N can occur because the zeolite content is capable of absorbing NH₄⁺ [19].

Application of cow manure increased N total by 40.54% (Table 4). Manure can increase the total N-content in the soil. Organic material from manure plays a role in inhibiting nitrification, so that N elements are not easily lost so that it can be used by plants. Organic matter is important for retaining water for supplying and retaining nutrients [20]. Zeolite gave a real effect to c-organic soil (Table 3). Zeolite with a dose of 5 t ha⁻¹ increased the c-organic by 24%. The use of ameliorant in acid soils can increase the soil C organic [21]. Treatment of cow manure 5 t ha⁻¹ yields the highest C-organic soil value which is 1.87%. Cow manure 5 t ha⁻¹ treatment resulted the increase of C-organic soil by 26.35% (Table 4).

C-organic is positively correlated with total soil N, and CEC, this shows soil organic matter has a positive effect, when the content of organic matter is high then the value of N total is also high. C-organic has high CEC which is derived from functional groups of organic acids such as carboxyl and hydroxyl. When the clusters are hydrolyzed it will produce a lot of negative charges. The increase in negative charge due to the process will lead to an increase in CEC.
Table 4. Effect of giving different types of manure to N-total, and C-organic

| Types of Manure | N total (%) | C-organic (%) |
|-----------------|-------------|--------------|
| Control         | 0.37a       | 1.48a        |
| Quail           | 0.41a       | 1.73b        |
| Cow             | 0.52b       | 1.87b        |

Description: The numbers followed by the same letters show no significant difference in the DMRT test of 5%.

Dose of zeolite and type of manure had significant effect to soil CEC (Table 5). An increase of value of soil CEC due to the applied zeolite based on laboratory analysis has been known that zeolite minerals have very high. Zeolites have high CEC values useful as cation adsorbers and binder and exchangers [22].

Table 5. Effect of Interaction of Zeolite Dosage and Manure on Soil CEC.

| Dose of Zeolite (t ha⁻¹) | Type of Fertilizer | Mean  |
|--------------------------|--------------------|-------|
|                          | Control            |       |
| 0                        | 23.56 a            |       |
| 2.5                      | 48.49 b            |       |
| 5                        | 52.48 b            |       |
| Mean                     | 41.51              | 47.67 |
|                          | 49.28              |       |

Description: The numbers followed by the same letters indicate different yet unreal on the DMRT test 5%.

Current study indicated soil CEC correlated positively with soil c-organic and N total of soil. Type of manure provides real effect to fresh weight of plant, manure gives high N nutrients that soybean crops can absorb N. High N uptake of nutrients can make maximum plants productivity, as plants growth and development will be optimal. Applying a single zeolite gave a significant effect on the nutrient uptake (Table 6). The highest N uptake in zeolite treatment with a dose of 5 t ha⁻¹ is 9.54%. Zeolite’s hollow structure channeled in all directions that it can store ammonium ions (NH₄⁺) and other gases as well as limiting volatilization and washing N from fertilizer [22].

Type of manure gives real effect on N uptake of plants (Table 6), with the highest nutrient uptake in cow manure was 9.8%. The increase in cow manure was 48.93% compared with control treatment. Amount of N absorbed by plants is closely related to the resulting dry weight of the plant. The increase of N nutrient uptake can stimulate better plant growth (plant dry weight), and vice versa. Correlation test between CEC and N uptake of a plant indicates positive interaction. This represents that increase in soil CEC will be followed by increased N uptake of plants. In addition, there was a positive correlation between total N soil with N uptake by soybean crops.

Table 6. Effect of dosing of zeolite and types of manure on N uptake

| Dose of Zeolite (t ha⁻¹) | N uptake (%) | Types of Manure | N uptake (%) |
|--------------------------|--------------|-----------------|--------------|
| 0                        | 6.22a        | Control         | 6.58a        |
| 2.5                      | 8.36ab       | Quail           | 7.72b        |
| 5                        | 9.54b        | Cow             | 9.8b         |

Description: The numbers followed by the same letters indicate different yet unreal on the DMRT test 5%.

Interaction between dose of zeolite and type of manure has a significant effect on a number of pods (Table 7). The highest increase of pod content was obtained at zeolite 5 t ha⁻¹ with a type of cow manure which increased by 129% compared to treatment without manure and zeolite. Cow manure in addition to improve soil conditions is also able to supply nutrients required by plants [23]. Production component is determined by the number of pods and weight of the pod content. The higher is a value of the component, the higher is its productivity.
Table 7. Effect of Interaction of Zeolite Dose and Type of Manure on Number of Soy Pods Contents

| Dose of Zeolite | Type of Manure | Mean |
|----------------|---------------|------|
|                | Control       | Quail| Cow  |
| 0              | 102 a         | 124 c| 193g |
| 2.5            | 113 b         | 145e | 193g |
| 5              | 132d          | 187f | 234 h|
| Mean           | 119           | 175  | 180  |

Description: The numbers followed by the same letters indicates no significant difference in the DMRT test of 5%

Amount of pod content with N uptake has a positive correlation. At the time of pod filling process, nitrogen is highly required as it is the main constituent of protein in a seed. Sufficient nitrogen availability will provide high-quality seed formation [24].

Table 8 shows that zeolite and manure gave significant effect on seed weight. An increase of seed weight was obtained at 5 t ha⁻¹ zeolite and 5 t ha⁻¹ cow manure of 56.01% compared with zeolite and quail manure treatment. The highest seed weight is generated by application of cow manure. Cow manure has high N, P, K nutrients absorbed by plants in sufficient quantities.

Table 8. Effect of Interaction of Zeolite Dose and Type of Manure at Weight of whole seeds

| Dose of Zeolite | Type of Manure | Mean |
|----------------|---------------|------|
|                | Control       | Quail| Cow  |
| 0              | 316 a         | 345 c| 416 d|
| 2.5            | 332 b         | 449e | 451 e|
| 5              | 334d          | 458f | 493 g|
| Mean           | 327           | 429  | 442  |

Description: The numbers followed by the same letters indicates no significant difference in the DMRT test of 5%

There was a strong positive correlation between seed weight and N tissue. Amount of nitrogen absorbed by plants through the soil is initially buried in the stems and leaves, after forming pods, it is then collected in the pod skin, the older is the pod, then most of nitrogen (80-85%) is absorbed into the seeds.

4. Conclusion
An interaction between applying zeolite and manure increases the value of CEC, total pod content and weight of whole batch. Giving dose of zeolite by 5 t ha⁻¹ with cow manure gave the highest yield, total pod content, and seed weight. Zeolite with dose of 5 t ha⁻¹ gives highest influence indicated by increased N total of 35.13% and increase of N uptake by 53.37%. Applying manures gives effect to total soil N and N uptake with cow manures give the highest influence. Based on the results of this study, the application of zeolite and cow manures with dose 5 t ha⁻¹ increases N total soil and soybean yield.

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