



Adding manure and zeolite to improve soil chemical properties and increase soybean yield

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ARTICLE INFO	ABSTRACT
<p>Keywords: Cow manure Seed weight Soybeans Organic fertilizers Zeolites</p> <p>Article history <i>Submitted:</i> 2020-04-09 <i>Accepted:</i> 2020-06-24</p> <p>* <i>Corresponding Author</i> <i>Email address:</i> isnaluthfa@gmail.com</p>	<p>Increasing domestic soybean production is an important part of the effort to reduce reliance on imports. One potential area for improvement is developing soybean crops in Alfisols. Alfisols require intensive effort due to their poor soil chemical properties. Manure and zeolite were proposed as candidate materials that could be used to improve soil chemical properties to support plant growth and increase the productivity of cultivated land. The experiment was designed to study the addition of manure and zeolite on soil chemical properties of Alfisols and soybean yield. The experimental design was arranged in a factorial completely randomized block design with two factors—three rates of zeolite (Z0 = 0 t ha⁻¹, Z1 = 2.5 t ha⁻¹ and Z2 = 5 t ha⁻¹) and three manure variables (P0 = no manure, P1 = 5 t ha⁻¹ cow manure, and P2 = 5 t ha⁻¹ quail manure)—with three replications. The results showed that a combination of 5 t ha⁻¹ zeolite and cow manure increased soybean yield. However, zeolite 5 t ha⁻¹ resulted in the greatest improvement in soil chemical properties—the highest CEC, soil organic matter percentage, and pH.</p>
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1. Introduction

In Indonesia, soybean is an essential food source. At roughly 39% protein, it is a palatable and cost-effective source of calories and nutrients (Aminah, Ala, Musa, Padjung, & Kaimuddin, 2017). While soybean cultivation has increased in response to demand, soybean consumption in Indonesia has outpaced soybean production. Domestic production satisfies approximately 35% of the demand, while as much as 55% rely on imports (Roessali, Ekowati, Prasetyo, & Mukson, 2017). Soybean imports cost the country around three trillion rupiahs per year. Comprehensive research into methods of increasing Indonesian soybean production and reducing the yield gap is needed (Abadi, Tastra, & Koentjoro, 2018).

Best management practices on marginal land include methods of increasing production, and marginal productivity can be improved through the application of research and technological developments (Shahid & Al-Shankiti, 2013). While there has been an increase in soybean productivity, expanding the production area to suboptimal lands has become the target strategy of the Indonesian government

(Wijanarko & Taufiq, 2016). Agricultural extension programs in Indonesia with promise for application in marginal areas including Alfisols. Alfisols are old soils that have a sufficiently high pH, and they are widely spread (Widiatmaka, Ambarwulan, Setiawan, & Walter, 2016). Alfisols land experiences intensive weathering and further development (Srinivasarao et al., 2014). In general, tropical Alfisols are highly weathered soils, which are low in native fertility, have high phosphorus sorptive potential and low cation exchange capacities (CEC) (Ajiboye, Oyetunji, Mesele, & Talbot, 2019).

Manure and zeolite are materials that could be used to improve soil properties to support and increase the growth and productivity of cultivated land. Improving the chemical properties of soil by the addition of suitable materials increases productivity, so that marginal land can be used for agriculture. The intensification of crop and livestock production has generated large amounts of bio-waste such as crop residue and animal manure (Jia et al., 2018). Enhancing the organic matter content of soil offers the best

improvement in the index of productivity and value for agricultural land.

Manures have been effectively used to increase and promote plant production for centuries (Tabitha, Wilson, & Joseph, 2018). Manure is an affordable source of organic material and easily available from the surrounding environment. Organic fertilizers such as manure are intended to preserve the land by improving the chemical, physical, and biological properties of the soil. In addition to increasing the nutrient content such as nitrogen (N), phosphorous (P), and potassium (K), manure can improve the biological properties of soil by increasing the population of biota in the soil. Manure may also improve the physical properties of soil by loosening soil structures and improving aeration and drainage (Supramudho, Syamsiyah, Mujiyo, & Sumani, 2012).

Zeolites—crystalline hydrated aluminosilicate with a framework structure containing pores occupied by alkali, water, and alkaline earth cations—are another abundant and inexpensive resource for soil improvement (Wang & Peng, 2010). In agriculture, zeolites act as soil conditioners and increase water use efficiency and nutrient conveyance resulting in increased crop yield. Zeolites can also serve as macronutrient supplements that have the advantage of acting as slow/controlled-release fertilizer (Jakkula & Wani, 2018). Zeolites can improve soil structure and nutrient content by decreasing leaching (Eprikashvili et al., 2016). High porosity and sieving properties cause natural zeolites to have high cation exchange capacity and selectivity (Santiago, Walsh, Kele, Gardner, & Chapman, 2016). The experiment for this study was conducted to increase soybean yield by examining the addition of manure and zeolite to improve the soil chemical properties of Alfisols. The results of this research will inform future research and help farmers to develop and improve soybean cultivation in Alfisols.

2. Materials and Method

This study was conducted from May to September 2018, in the Alfisol experimental fields of Sukosari, Jumantono District, Karanganyar Regency, Central Java, at 7°37'49.9" S and 110°56'54.40" E, and at an altitude of 180 masl. Plant and soil analyses were carried out in the Soil Chemistry and Fertility Laboratory of Faculty Agriculture, Sebelas Maret University, Surakarta. The experimental design was arranged in a completely randomized block design consisting of two factors—three rates of zeolite: Z0 = 0 t ha⁻¹, Z1 = 2.5 t ha⁻¹, and Z2 = 5 t ha⁻¹, and three variations of manure: no manure, cow manure (5 t ha⁻¹), and quail manure (5 t ha⁻¹)—with three replications.

Plots of 1 m x 2 m were selected. Gema variety soybeans (a cross of the Shirome and Wilis varieties) were sown at 20 cm x 25 cm spacing, and each hole was planted with two seeds. Where used, manure and zeolite were applied before planting during soil cultivation by scattering appropriate amounts evenly over the soil surface and then tilling thoroughly.

Soil samples from each treatment were collected for chemical analysis at the last harvest from the rooting area. The soil samples were air-dried for a week and sieved through 0.5 mm and 2 mm sieves before measurement. The soil was

initially examined for pH using a pH meter, C-organic matter using the Walkley and Black method, soil organic matter using the Walkley and Black method, and CEC using an ammonium acetate solution and pH 7 adjustment. The results are shown in Table 1.

Table 1. Characteristics of initial soil, quail manure, cow manure, and zeolite.

Chemical Properties	Soil	Quail	Cow	Zeolite
pH	5.4	-	-	-
N total (g kg ⁻¹)	0.26	1.32	1.40	-
P ₂ O ₅ (mg kg ⁻¹)	4.45	4.54	4.41	-
K ₂ O (cmol kg ⁻¹)	0.22	1.51	1.40	-
C-organic (g kg ⁻¹)	1.15	17.56	19.94	-
Soil Organic Matter (%)	1.93	-	-	-
C/N Ratio	4.42	13.31	14.30	-
CEC (cmol kg ⁻¹)	18.93	-	-	128.20

Source: Results of Analysis of the Soil Science Laboratory Faculty of Agriculture, Sebelas Maret University.

The observed variables were plant height, fresh weight matter, dry weight matter, number of filled pods per plant, and seed weight. Plant height was measured by measuring the distance from the ground to the top of a plant using a measuring scale. Fresh weight matter was measured by weighing all fresh matter, while dry weight matter was measured by weighing all dried plants. The number of filled pods was determined by counting filled pods per plant. Seed weight was generated by weighing all the seeds from each treatment. All plant growth and yield variables were generated from measuring five randomly selected plant samples. It was tested by analysis of variance at 5% significance level; the difference between treatments was tested using the Duncan Multiple Range Test (DMRT) at a rate of 5%; and a correlation between parameters measured with the Pearson correlation test using SPSS.

3. Results

3.1. Plant growth and soybean yield

The results (Table 2) show the addition of manure and zeolite significantly affected the number of filled pods and seed weight. Table 2 shows that manure and zeolite—individually and together—significantly increased the number of filled pods. The highest increase in the number of filled pods was obtained by cultivating zeolite, 5 t ha⁻¹, with cow manure, 5 t ha⁻¹, which increased the yield by 129% compared to no treatment with zeolite or manure. An increase in seed weight was 56.01% observed between zeolite, 5 t ha⁻¹, and cow manure, 5 t ha⁻¹, when compared to no treatment. Overall, the highest seed weights were produced by adding organic fertilizer, especially cow manure. Table 2 shows that manure and zeolite, individually and combined, did not significantly affect plant height and dry weight matter.

Manure significantly increased fresh weight matter (Fig. 1). Significant differences between quail and cow manure were noted, but the addition of zeolite alone or zeolite in conjunction with manure did not affect fresh weight matter.

The highest yield of fresh weight matter was seen with cow manure—123.10 g plant⁻¹—followed by quail manure—114.75 g plant⁻¹. Fresh weight matter with cow manure was not dramatically different than quail manure, but it was higher than both quail manure and no manure.

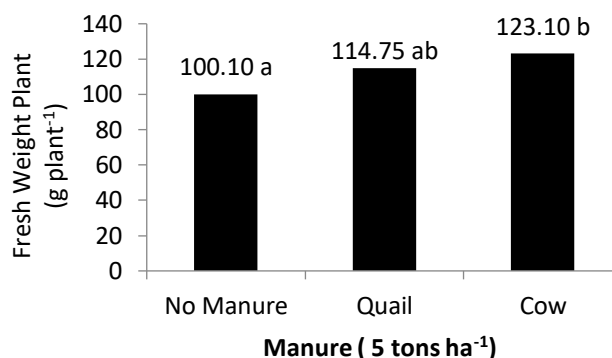


Figure 1. Effect of manure addition on the fresh weight matter.

Table 2. Effects of manure and zeolite on plant height, dry weight matter, number of filled pods, and seed weight.

Types of Manure	Rates of Zeolite	Plant Height (cm)	Dry Weight Matter (g plant ⁻¹)	Number of Filled Pods (pods plant ⁻¹)	Seed Weight (g plot ⁻¹)
No Manure	0 t ha ⁻¹	22.8	15.62	35 a	372.20 a
Quail Manure		24.2	16.10	41 c	405.78 c
Cow Manure		26.9	17.65	64 g	489.42 d
No Manure	2.5 t ha ⁻¹	27.3	18.36	38 b	390.16 b
Quail Manure		27.4	18.69	48 e	527.74 e
Cow Manure		26.4	18.50	64 g	530.36 e
No Manure	5 t ha ⁻¹	26.8	17.81	44 d	393.37 b
Quail Manure		29.0	19.61	62 f	539.11 f
Cow Manure		29.4	20.28	78 h	580.26 g

Remark: Numbers followed by the same letters in the same column showed no significant differences based on the DMRT level of 5%.

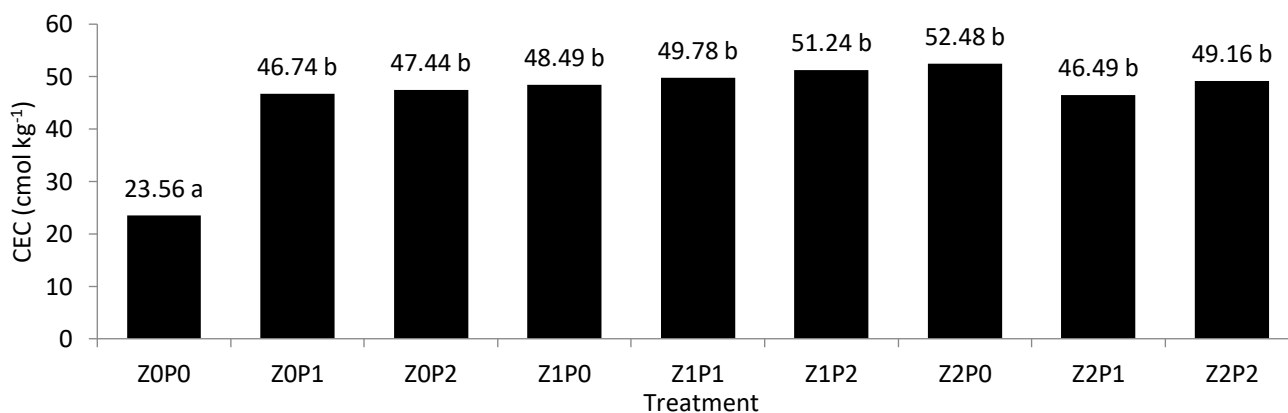


Figure 2. Effect of interaction of zeolite and manure on cation exchange capacity (CEC)



Figure 3. Effect of doses of zeolite on pH.

Table 3. Effect of zeolite quantities and manure types on soil organic matter.

Doses of Zeolite (ton ha ⁻¹)	Soil Organic Matter (%)	Types of Manure	Soil Organic Matter (%)
0	2.61 a	No Manure	2.61 a
2.5	3.03 b	Quail Manure	2.98 b
		Cow Manure	3.23 b
5	3.26 b		

Remark: Numbers followed by the same letters in the same column showed no significant differences based on the DMRT level of 5%.

3.2. Soil Chemical Properties

The results show that the addition of manure, zeolites, and both combined significantly affected CEC (Fig. 2). In this research, 5 t ha⁻¹ of zeolite yielded the highest result—52.48 cmol kg⁻¹—a 123% increase over no treatment. There was no significant difference between zeolite doses of 2.5 t ha⁻¹ and 5 t ha⁻¹ with either manure type. There was an increase in the value of soil CEC noted. This result was not unexpected; zeolite was applied based on the results of laboratory analyses and zeolite minerals have a very high CEC of 128.20 cmol kg⁻¹.

Table 3 shows that each dose of zeolite and manure significantly affected the percentage of soil organic matter. The addition 5 t ha⁻¹ of zeolite resulted in the highest soil organic matter (3.26%), while the lowest was recorded in samples with no manure and no zeolite treatments (2.61%), a variance of approximately 25%. No significant difference in soil organic matter was observed between applications of 5 t ha⁻¹ and 2.5 t ha⁻¹ of zeolite.

The addition of zeolite did have a significant effect on pH (Fig. 3). The results of soil analysis after the field experiments showed that the addition of zeolite increased pH; however, neither type of manure alone, nor the interaction between zeolite and either manure type had a significant effect on soil pH. The addition of 5 t ha⁻¹ zeolite recorded highest soil pH (6.0); an increase of approximately 3.45% compared with the control sample.

4. Discussion

The addition of manure and zeolite significantly increased the number of filled pods and seed weight (Table 2). Manure application in Myint, Yamakawa, & Zenmyo (2009) showed similar high seed yield results. The results may be explained by the N, P, and K nutrients contained in manure which can be absorbed by plants. According to Cairo et al. (2017), zeolite also retains nutrients in the root zone of plants until required. In the instant results, cow manure combined with 5 t ha⁻¹ of zeolite yielded the highest number of filled pods and seed weight. According to Das, Jeong, Das, & Kim (2017), the use of composted cow manure is preferred in efforts to increase soil organic matter and decrease the risk of N loss by leaching. This is consistent with Yunilasari, Sufardi, & Zaitun (2020) who showed that manure is known to be an organic material that can improve nutrient supply and soil structure. In addition, increasing the storage time of cow manure prior to application also increases the ratio of inorganic to organic P and raises the concentration of water-soluble P.

The incorporation of zeolite reduced dissolved ammonia gas and absorbed ammonium (Lefcourt & Meisinger, 2001). (Wiyantoko & Rahmah, 2017) reported that zeolite serves to improve nitrogen efficiency, while Herliana, Harjoso, Anwar, & Fauzi (2019) reported that nitrogen was absorbed by plants into stems and leaves, then collected into pods and absorbed into the seeds. So, prior research and the instant experiment demonstrate that the addition of both manure and zeolite can increase the number of filled pods and seed weight.

Fig.1 shows that manure increased the fresh weight matter. This result is similar to the results of Fatahi, Mobasser, & Akbarian (2014) who showed that manure

produces a significant increase in fresh weight matter. The highest fresh weight matter yield was seen with the application of cow manure, but the return was not notably different from quail manure. The lowest fresh weight matter was found in the control group. These results are likely due to the high nutrient and organic matter content of manure which may increase the availability of soil nutrients (Zaman, Chowdhury, Nahar, & Chowdhury, 2017).

None of the treatments affected plant height and dry weight matter (Table 2). Plants did not exhibit a response in either height or dry weight matter to the addition of manure or zeolite. This is probably explained by the genetic characteristics of the plants or because manure and zeolite are not able to provide both macro and micronutrients.

The treatments did have a significant effect on CEC (Fig. 2); in the instant research, 5 t ha⁻¹ of zeolite yielded the highest result (52.48 cmol kg⁻¹). These results are almost identical to the results of a study conducted by Gholamhoseini et al. (2013), which showed that the application of manure and zeolite tends to increase soil CEC. Ozbahce, Tari, Gönülal, Simsekli, & Padem (2015) observed that CEC increased with the increase in zeolite doses, and Nainggolan, Suwardi, & Darmawan (2009) that noted that zeolite has a high CEC value, which is useful in adsorption and binding and cation exchange. Zeolite is a natural material that has a high CEC (120-180 cmol kg⁻¹) capable of exchanging and adsorbing cations such as NH₄⁺ (Kharisun, Rif'an, Budiono, & Kurniawan, 2017).

Zaidun et al. (2019) explained that the increase in CEC is influenced by pH; when pH increases, the minerals become negatively charged and attract the positively charged cation minerals. Zeolites are often applied for pH buffering (Zaidun et al., 2019), and in the instant results, zeolite increased soil pH. These results are consistent with those obtained by Truc & Yoshida (2011) who have demonstrated that the addition of zeolite usually increases pH levels due to its ability to absorb alkaline cations—Ca²⁺ and Mn²⁺. The adsorption of the base cations reduces the amounts that are washed away and to be replaced by acid cations—Al³⁺, Mn²⁺, and H⁺ (Lin, Lo, Lin, & Lee, 1998). Zeolite contains aluminosilicate which will produce OH⁻ if hydrolysis occurs. Hydroxide ions—OH⁻—are bound to acid cations. As the acid cations decrease, soil pH increases. Zeolite change soil properties like pH, decrease metal mobility in contaminated soil (Li, Shi, Shao, & Shao, 2009), improving the productivity of suboptimal lands.

Finally, these results showed that zeolite can increase soil organic matter. Using zeolites to conserve soil organic matter that will help further to improve the efficiency of soil water and nutrient use (Ramesh & George, 2019). The addition of organic matter through manure undergoing a decomposition process also increases soil organic matter (Xie et al., 2014). Adding organic material like cow or quail manure to the soil will increase crop productivity because the decomposed and decomposing organic matter will increase soil fertility and the availability nutrients. Gupta, Aneja, & Rana (2016) noted that cow manure has the ability to increase soil fertility through its organic matter compounds. The combination of manure and zeolite has the greatest positive effect on soil productivity: zeolite increases pH, cation exchange capacity, and soil

organic matter (Chaiyaraksa & Tumtong, 2019; Li et al., 2009), and its effects persist despite the decomposition of organic matter contained in manure (Truc & Yoshida, 2011), a process that positively contributes N, P, and K to the soil.

5. Conclusion

This research demonstrates an improvement in soil productivity and soybean yields through the application of manure and zeolite. The addition of manure and zeolite improved the chemical properties of soil and improved soybean yield without an increase in plant height or dry weight matter. Cow manure and 5 t ha⁻¹ zeolite yielded the highest number of filled pods and greatest seed weight. However, zeolite 5 t ha⁻¹ had the greatest improvement on soil chemical properties, yielding the highest CEC, soil organic matter, and pH.

Declaration of Competing Interest

The authors declare no competing financial or personal interests that may appear and influence the work reported in this paper.

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