Original Research Article

ROCK PHOSPHATE, ZEOLITE AND QUAIL MANURE TO ENHANCE POTASSIUM UPTAKE AND YIELD OF SOYBEAN ON ALFISOLS

ABSTRACT

Soybean seeds are the source of vegetable protein-based that most consumed in Indonesia, but apparently the production is unable to compensate the rate of increase in community needs. This study aims to determine the effect of Rock Phosphate (RP), zeolite and quail manure to enhance potassium (K) uptake and yield of soybean in Alfisols. A field experiment was conducted in June-October with a single factor Randomized Complete Block Design (RCBD) consisting of 9 treatments and 3 blocks (replicates). The dosage of RP, zeolite and quail manure used was 0 t ha^{-1}, 2.5 t $ha^{-1}$and 5 t ha^{-1}. The results showed that zeolite 5 t ha^{-1} + quail manure 2.5 t ha^{-1} tended to increase K uptake. The combination of RP 2.5 t ha^{-1}+ quail manure 5 t ha^{-1} significantly increases the number of filled pods and seed weight per plot. RP 5 t ha^{-1} + zeolite 5 t ha^{-1}+ quail manure 5 t ha^{-1} also affects the number of filled pods and seed weight per plot. The treatment zeolite 2.5 t ha^{-1}+ quail manure 2.5 t ha^{-1}also affects the number of filled pods.

Keywords: Soybean, Alfisols, Rock Phosphate, Organic Manure, Zeolite

1. INTRODUCTION

Soybean seeds are the source of vegetable protein-based that most consumed in Indonesia. Soybean seed needs continue to increase along with increasing population growth, per capita income, and public awareness of food nutrition. National soybean production fell 7.06% from 963.18 tons in 2015 to 887.54 tons in 2016 [1]. The average soybeans consumption per year in Indonesia is 2.2 million tons, but ironically, 67.99% of soybean needs are obtained from imports [2]. Therefore there is a need to increase soybean production in order to meet the needs and overcome import dependence.

Land expansion by utilizing the potential of suboptimal lands such as Alfisol need to increase soybean production. Alfisol is a potential soil for agriculture, but there are still obstacles that need to be considered in its management [3]. Alfisols have acidic pH due to high Al and Fe reduction and low cation exchange capacity (CEC). In addition, Alfisol has low levels of organic matter and low macronutrient content such as potassium [4].

Potassium (K) is an essential nutrients needed in large quantities for plant growth. The content of K in the soil is quite high, but plants can only absorb 1-2% of the total K soil [5]. Potassium plays a various role in physiological processes in plants such as photosynthesis, protein synthesis, and enzyme activator [6]. The K element also helps increasing plant resistance of pests, diseases, and drought stress. Adequate availability and uptake of K increases plant growth and yield, as well as the quality of crop yields [7].

Rock phosphate (RP), zeolite and quail manure is expected to increase the K availability and uptake so that soybean production increases. RP contains a group of phosphorus oxides [Ca3 (PO4) 3F2]. The Ca+ in rock phosphate has a base effect so that the soil pH increases. Zeolite is an aluminosilicate crystal mineral that has the ability as an ion absorber and exchanger and pH buffer [8]. Zeolite has high CEC and naturally contain K. Zeolite is negatively charged that can absorb K ions and prevent K from washing.

Quail manure has the potential to be used as a source of organic material because its availability is abundant and not yet widely used. Adding organic manure as a source of organic material can increase total N, available P, Ca, and K, and increase land productivity [9]. Organic manure in the study [10] was able to increase soil fertility, nutrient uptake, plant height, plant dry weight, number of pods per plant, and dry weight of soybean. This study aims to determine the effect of RP, zeolite, and quail manure on K uptake and soybean seed yield on Alfisol.

2. MATERIALS AND METHODS

2.1 Study Area

The filed experiment was carried out on Alfisol land in Soko, Sukosari Village, Jumantono Subdistrict, Karanganyar, Surakarta, Indonesia in July-October 2018. The research location was at an altitude of 180 meters above sea level with coordinates 7º37'41"S and 110º57'7"E. Laboratory analysis was carried out at the Laboratory of Chemical and Soil Fertility, Faculty of Agriculture, Universitas Sebelas Maret, Surakarta. The materials used in the study were soybean DEGA 1, rock phosphate, zeolite, and quail manure. The tools used include spectrophotometers, flamefotometers, analytical scales, and ovens.

2.2 Experimental Design

The experimental design used was a single factor Complete Randomized Block Design (RAKL) consisting of 9 treatments with 3 block (replicates), so there were 27 experimental units. Treatments include:P0: Control, P1:RP 2.5 t ha^{-1}+ quail manure 5 t ha^{-1}, P2: zeolite 2,5 t ha^{-1} + quail manure 5 t ha^{-1}, P3: RP 2,5 t ha^{-1} + zeolite 2,5 t ha^{-1}+ quail manure 5 t ha^{-1}, P4: RP 2,5 t ha^{-1}+ quail manure 2,5 t ha^{-1}, P5: zeolite 2,5 t ha^{-1}+ quail manure 2,5 t ha^{-1}, P6: RP 5 t ha^{-1}+ quail manure 2,5 t ha^{-1}, P7: zeolite 5 t ha^{-1} + quail manure 2,5 t ha^{-1}, P8: RP 5 t ha^{-1} + zeolite 5 t ha^{-1} + quail manure 5 t ha^{-1}.

2.3 Crop Management

The experimental field was divided into 3 equal blocks (replicates) with an inter-block spacing of 40 cm. Each block divided into 9 equal plots (1.7 m x 3 m) with interplot spacing of 20 cm, giving a total of 27 lots. Laboratory analysis was conducted to determine the characteristic of RP, zeolite, quail manure, initial soil, and post-harvest soil. Soil samples from each plot were taken before the application of treatment and planting. Application of RP, zeolite, and manure according to predetermined treatment. Soybean seed was planted directly into planting hole with a plant spacing of 25 cm x 25 cm, so there were 84 planting holes. Plant maintenance includes replanting, watering as well as control of weed, pests and diseases. At the flowering stage, (4 weeks after planting) K tissue and K uptake were measured. Soybean harvesting was carried out at 70 days after planting. Post-harvest soil samples were collected from each plot to measured soil pH, organic matter, CEC and available K. Soybean growth and yield variables was observed i.e. plant height, dry matter, tissue K, K uptake, number of filled pods and seed weight per plot.

2.4 Statistical Analysis

All the collected data were subjected to analysis of variance (ANOVA) using SPSS statistics package. Significant ANOVA results were tested further using the Duncan Multiple Range Test (DMRT) at 5%.

3. RESULT AND DISCUSSION

3.1 Initial Soil Condition

Alfisols on the experimental field had low soil fertility with 1.65% organic C (low), 2.85% organic matter (medium) and pH 4.9 (acid). Rao and Reddy [11] state that soil conditions with pH <6 will inhibit soybean growth because soil pH affects solubility and nutrient availability [12]. Soil with low pH will have a relatively low CEC, because more $H+$ ions are attached to colloids and cause soil cations to be pushed into the soil solution. This condition, as reported by Sudadi et al. [13] in their study that Alfisols had low CEC (5.7 me/100g) and very low available K (0.33 me/100g). Application of RP, zeolite and quail manure is needed to improve the soil condition in providing and increasing nutrient uptake to support optimal plant growth and yield.

3.2 Characteristic of RP, zeolite dan quail manure

Rock phosphate, zeolite and quail manure had a pH of 7.9-8.3 (moderately alkaline) and expected to improve the soil conditions of the experiment field which has low pH. Quail manure has a N content of 1.32%, P 4.54%, K 1.51%, and C-org 17.56% with C / N 13.31 [14]. RP is slow realese phosphate source, and manure contains organic acids that can increase the solubility of RP [15]. Zeolite with CEC 128.6 me / 100g meet the Indonesian National Standar of zeolite quality requirements. Chmielewska and Lesný [16] state that zeolite have pores that contain cations and channels that are broad in their structure, so that CEC is important parameter to determining the quality of zeolite.

Tabel 1. Effect of rock phosphate, zeolite and quail manure on soil pH, organic matter, cation exchange capacity and available K

Treatment	pH	Organic matter (%)	Cation Exchange Capacity (me/100g)	Available K (me/100g)
P0	6.4a	2.86a	41.79a	0.87a
P1	6.8b	3.06a	47.23a	1.00a
P2	6.5a	2.67a	48.07a	0.78a
P3	6.8b	3.58a	45.06a	0.82a
P4	6.7b	2.59a	50.18a	0.62a
P5	6.3a	3.20a	45.04a	1.09a
P6	6.9b	3.37a	43.96a	1.10a
P7	6.4a	3.24a	45.36a	1.36a
P8	6.8b	3.17a	40.26a	0.86a

The numbers followed by the same letters show no significant difference in the DMRT 5%

3.3 Soil pH

Soil pH is a characteristic that describes the amount of H + ion concentration in the soil. Application of RP, zeolite and quail manure significantly increase the soil pH (p=0.00). Combination of RP 2.5 t ha-1 + quail manure 5 t ha^{-1} , RP 2.5 t ha^{-1} + zeolite2.5 t ha-1 + quail manure 5 t ha^{-1} , RP 2.5 t ha^{-1}+ quail manure 2.5 t ha^{-1}, RP 5 t ha^{-1} + quail manure 2.5 t ha^{-1} and RP+zeolite+manure each t ha^{-1} gave better results than the control treatment, while other treatments showed the same results with the control treatment.

The pH value in various treatments were compared with the initial soil pH (4.9) has increased. The increase in pH occurs due to the RP, zeolite and quail manure given to the soil have a higher pH of 7.9-8.3 (moderately alkaline). Quail manure releases organic compounds in the form of organic acids that are able to bind H+ ions so that the soil pH increases. Appropriate soil pH will increase nutrient availability, growth and yield of plants [12].

Treatment with the addition of RP gives an increase in pH higher than treatment without RP. RP is slow realese and has a Ca content that has an alkaline effect. Acidic initial soil conditions tend to accelerate the solubility of RP [17], which has implications for increasing pH.

3.4 Organic Matter

Statistical analysis showed that RP, zeolite and quail manure did not affect soil organic matter. Combination of Rp 2.5 t ha^{-1} + quail manure 2.5 t ha^{-1} has the lowest organic matter content (2.59%). Treatment of RP 2.5 t ha^{-1}+ quail manure 5 t ha^{-1} + zeolite 2.5 t ha^{-1} tends to increase organic matter better than other treatments with organic matter content 3.58%.

RP+zeolite+quail manure each 5 t ha^{-1} only increases the organic matter 11.07%, while the combination of RP 2.5 t ha^{-1} + zeolite 2.5 t ha^{-1} + quail manure 5 t ha^{-1} tends to increase soil organic matter 25.41% compared to treatment control. Zeolite is able to influence soil aggregate stability [18]. Soils with stable aggregates have the ability to infiltrate water and high nutrient retention. Zhang et al. [19] stated that manure also increases soil aggregation which physically protects soil organic matter from degradation by microorganisms and exoenzymes.

3.5 Cation Exchange Capacity (CEC)

Cation Exchange rtCapacity (CEC) is the ability of the soil to bind and exchange cations. Analysis results showed that the application of RP, zeolite and quail manure did not affect the soil CEC. Table 1. shows that overall soil CEC tends to increase compared to initial soil condition. Soils with high CEC are able to absorb and provide nutrients better than low CEC. Figure 1 shows a combination of Rp. 2.5 t ha^{-1} + quail manure 2.5 t ha^{-1} tends to increase CEC 20.08% compared to control treatment. RP is a rock with hight content of phosphate (P). Yuniarti et al. [20] reported that the administration of P and organic matter to the soil contributed to adding negative charges to the soil causing CEC to increase.

3.6 Available K

Potassium (K) is a macro essential nutrient that highly mobile and is need in large quantities for plant growth. K availability in the soil determines the amount of K that can be absorbed by plants [21]. Application of RP, zeolite and quail manure did not effect the K availability in the soil (Table 1.). Combination of zeolite 5 t ha^{-1} + quail manure 2.5 t ha^{-1} tended to increase K available 56.18% compared to the control treatment. Manure as a source of organic matter contains humus which can increase the release of K elements and determine the dynamic balance status of potassium in the soil [22]. Organic matter can increase the ability to hold water so that soil moisture is maintained. Soil under humid conditions will affect the release mechanism of K which is absorbed to become available to plants. Zeolite can increase K availability due to the capability of zeolite to absorb K+ from soil solution and prevent K+ from leaching. Zeolite also contain basic cations such as K and Ca, as well as macro elements that can be added to the soil as a plant nutrient [23].

Table 2. Effect of rock phosphate, zeolite and quail manure on K uptake, plant height and dry matter

Treatment	K Uptake (mg/plant)	Plant Height (cm)	Dry Weight (gram)
P0	155.98a	21.33a	4.66a
P1	419.80a	27.95b	12.76a
P2	370.92a	25.97b	8.25a
P3	379.53a	26.97b	9.17a
P4	385.08a	25.87b	9.37a
P5	503.55a	25.41ab	10.36a
P6	505.67a	25.26ab	12.04a
P7	509.83a	25.13ab	11.40a
P8	375.85a	25.07ab	10.22a

The numbers followed by the same letters show no significant difference in the DMRT 5%

3.7 K Uptake

Potassium (K) absorbed by plants in the form of exchangeable K and K+ ions in the soil solution. RP, zeolite, and quail manure application tended to increase K uptake compared to the control treatment which had a K uptake of 155.98 mg/plant. The highest K uptake was found in the treatment of zeolite 5 t ha^{-1} + quail manure 2.5 t ha^{-1} which was 509.83 mg/plant. Zeolite naturally contains K and increases K availability in the soil and prevents K from leaching [24]. As reported by Rabai et al. [25] that zeolite increases the concentration and uptake of K as well as the nutrient use efficiency of K elements by plants.

Treatment with quail manure 2.5 t ha^{-1} tended to give higher K uptake than 5 t ha^{-1}. Quail manure contain organic material that capable to realese K nutrients into the soil solution. However, excessive application of manure can result in leaching up soil cations such as K, Ca and Mg which cause decreased of CEC and soil pH [26], those condition can inhibit nutrient absorption by plant roots

3.8 Plant Height

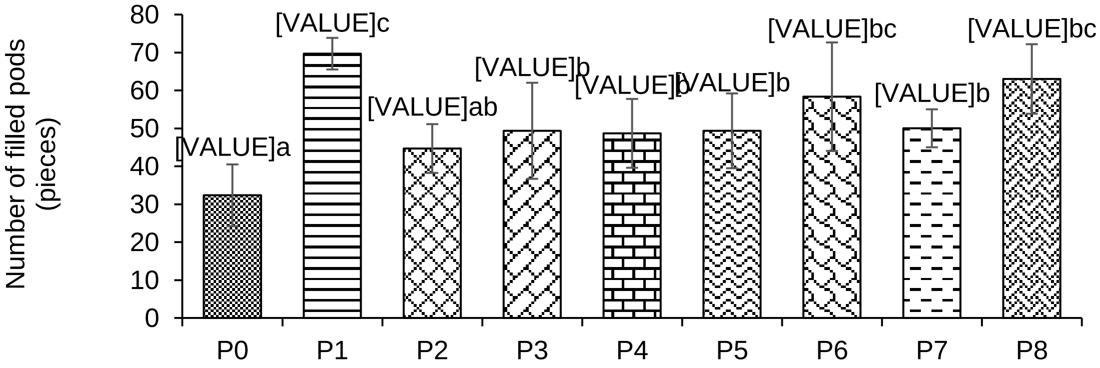
Plant height is one of the plant growth indicator and its irreversible. Table 2. showed that RP, zeolite and quail manure were significantly increase the plant height (p=0,006). The RP 2.5 t ha^{-1} + quail manure 5 t ha^{-1}; zeolite 2.5 t ha^{-1} + quail manure 5 t ha^{-1}; RP 2.5 t ha^{-1} + zeolite 2.5 t ha^{-1} + quail manure 5 t ha^{-1}; and RP 2.5 t ha^{-1} + quail manure 2.5 t ha^{-1} significantly increases plant height. Other treatments have similar effect with control treatment.

Plant height in each treatment has increased every week, and application of RP, zeolite and quail manure was able to increase plant height 21.29-31% compared to control treatment. RP contains P elements which essential in the formation of root nodules in legume plants. Zeolite can increase the water holding capacity due to its physical properties, so it can improve soil structure and increase macro and micro pores in the soil [27]. Manure as organic material supply plant nutrients that stimulate root growth [28]. A proper root system will promote nutrient absorption and optimal plant growth.

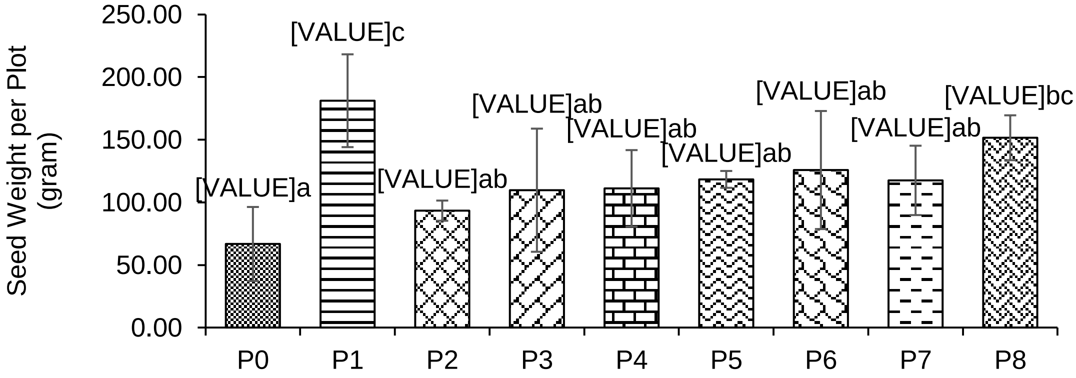
3.9 Dry Matter

Dry weight determined the amount of assimilates that translocated to plant organs as the result of metabolic processes in the form of photosynthesis, nutrient absorption and water. The amount of assimilate produced during growth is related to the rate of photosynthesis [29]. The control treatment had the lowest dry weight of 4.66gram. Combination of RP 2.5 t ha^{-1} + quail manure 5 t ha^{-1} tended to give the highest result compared to other treatments. Wang et al. [30] stated that potassium plays an important role in water retention in plant tissues, as well as cell turgor during the opening and closing of stomata. Potassium in the mechanism of opening and cloosing of stomata related to plant physiology processes, especially CO_2 fixation which will produce assimilates to meet plant needs for proper gowth.

Dry weight was positively correlated with K uptake (r = 0.808; p = 0,000). Accumulation of photosynthate during plant growth related to the rate of photosynthesis, and potassium plays an important role in these process. Wang et al. [30] stated that adequate of K availability and K uptake will increase the total accumulation of plant dry weight.



The numbers followed by the same letters show no significant difference in the DMRT 0.05
Figure 1. Effect of rock phosphate, zeolite and quail manure on number of filled pods



The numbers followed by the same letters show no significant difference in the DMRT 0.05
Figure 2. Effect of rock phosphate, zeolite and quail manure on seed weight per plot

3.10 Number of Seed per Pods

Number of seed per pods was significantly increase due to the application of RP, zeolite and quail manure. The treatments with significant effect were RP 2.5 t ha^{-1} + quail manure 5 t ha^{-1}; RP 5 t ha^{-1} + quail manure 2.5 t ha^{-1}; and RP 5 t ha^{-1} + zeolite 5 t ha^{-1} + quail manure 5 t ha^{-1}. The increase in the number of pods of these treatments were 80.41-115.46% compared to the control treatment. Other treatments showed similar result, except the zeolite 2.5 t ha^{-1} + quail manure 5 t ha^{-1} which showed the same effect as the control treatment.

RP as a source of phosphate (P) was increases the soil pH (table 1.) and its also effect the availability of P in the soil. Legumes use P for the formation of pods and seed filling during the generative phase. The absorbed P is translocated from the roots and leaves to the seed [31]. The P and K elements are needed in hight amount for proper plant growth and development. Fageria and Oliveira [32] found that the combination of both P and K gave a large increase in plant production compared to the effects of each individual element. These interactions indicate a synergy between P and K [33].

The number of filled pods positively correlated with dry weight (r = 0.835; p = 0,000). Sabilu et al. [34] stated that photosynthate in the generative phase widely used for the process of pods formation and seed filling.

3.11 Seed Weight per Plot

The combination of RP 2.5 t ha^{-1} + quail manure 5 t ha^{-1} and RP 5 t ha^{-1} +zeolite 5 t ha^{-1} + quail manure 5 t ha^{-1} significantly increases the seed weight per plot. Other treatments showed the similar effect with the control treatment. Seed weight per plot correlates with the number of filled pods (r = 0.921, p = 0,000). Manure does not only contain macro and micro nutrients needed by plants, but also produces derivative products in the form of humic acid [35] . Mindari et al. [36] mentioned that humic acid can increase K uptake so that it can trigger ion transport and assimilation of carbohydrates and affected the increase of plany yield.

4. CONCLUSSION

Rock phosphate , zeolite and quail manure is needed to increase K uptake and soybean yield in Alfisol. RP, zeolite and quail manure tend to increase potasium uptake . Potassium plays an important role in photosynthesis and translocation of photosinthate to support plant growth and production. The combination of RP 2.5 t ha^{-1} and quail manure 5 t ha^{-1} gave the highest yield on soybean yield variables compared to other treatments, and significantly increased the number of filled pods and seed weight per plot

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