



# Effects of Various Ameliorants on pH, Phosphorus Availability and Soybean Production in Alfisols

V.A. Triatmoko, S. Minardi, H. Widiyanto, J. Syamsiyah

10.18805/IJArE.A-458

## ABSTRACT

Alfisols have inherent potential to increase Indonesia's soybean production, however, alfisols also known for its low phosphorus availability. Field experiment using ameliorants consisting of quail manure, zeolites and rock phosphate was conducted to increase phosphorus (P) availability and soybean production. The aim of this study is to evaluate the effects of ameliorant combinations for improving phosphorus availability and its correlation to soybean production in alfisols. Randomized complete block design with single factor was used, with 9 combinations of ameliorants under study (P0 – P8). Obtained results showed that phosphorus availability is increased up to 72.6% and soybean yield upto 75.9%. Correlation of phosphorus availability and soybean production was significant ( $r = 0.854$ ). Finally, the best treatment to increase phosphorus availability and soybean production is quail manure 2.5 t.ha<sup>-1</sup> + rock phosphate 5 t.ha<sup>-1</sup>).

**Key words:** Alfisols, Phosphorus, Rock phosphate, Soybean, Zeolite.

## INTRODUCTION

Soybean production area decreased in the last decade at least 0.97% per year based on Indonesia's statistic source (BPS) in 2015. Population growth, adds the favour creating a wide gap between soybean production and consumption. The decrease in soybean production is due to continuous use of inorganic fertilizer, climate change and other environmental factors. To keep up with soybean consumption, soybean production should be increased and potential type of soil for soybean cultivation is alfisols.

Alfisols are in general acidic with poor fertility status (Bhat *et al.* 2017). Harter (2007) found soil pH has an important role in nutrient availability including phosphorus. Harter also mentioned, soils with pH below 5.5 with have high amounts of Al<sup>3+</sup> and Fe<sup>3+</sup>. Hence, phosphorus bond with aluminium (Al) or iron (Fe) in alfisols, or in some cases with soil clay (Fink *et al.* 2016) which cause phosphorus not available for plants. Meanwhile, soybean requires high amount of phosphorus according to Heard (2005) and Monsanto Technology (2015).

Three types of ameliorants were used in this study: quail manure, zeolites and rock phosphate. Rostami *et al.* (2013) found that addition of cow manure is able to help in binding Fe, Mn and Zn with soil colloid. Related to alfisols, Pinto *et al.* (2013) stated that organic matter is able to increase phosphorus availability indirectly through inhibiting aluminium oxide crystallization. Khasawneh and Doll (1978) found that use of rock phosphate most effective on acid soil and pH has an important role to enhance phosphorus availability in soil.

Use of manure and rock phosphate was studied by Akande *et al.* (2005). He showed that manure helps to increase rock phosphate effectiveness and on increasing soil phosphorus availability. Zeolites are known for its ability to support crop cultivation through enhancing nutrients and

Department of Soil Science, Sebelas Maret University, Surakarta, Central Java-57126, Indonesia.

**Corresponding Author:** V.A. Triatmoko, Department of Soil Science, Sebelas Maret University, Surakarta, Central Java-57126, Indonesia. Email: [vercillia.anggraeni12@gmail.com](mailto:vercillia.anggraeni12@gmail.com)

**How to cite this article:** Triatmoko, V.A., Minardi, S., Widiyanto, H. and Syamsiyah, J. (2020). Effects of Various Ameliorants on pH, Phosphorus Availability and Soybean Production in Alfisols. Indian Journal of Agricultural Research. 54(4): 531-535.

**Submitted:** 28-06-2019 **Accepted:** 27-02-2020 **Published:** 16-05-2020

water storage (Millosevic, 2009). Use of zeolites will help to increase soil CEC and plant phosphorus adsorption. Study of zeolites application (Bernardi *et al.* 2010) showed that zeolites helps to increase the effectiveness of rock phosphate. The objectives of this study is to know the best ameliorants and its combination to increase soil phosphorus availability and its relation with soybean yield.

## MATERIALS AND METHODS

This study was carried out in Sukosari district, located in Central Java, Indonesia from 5 May 2018 – 5 August 2018. Laboratory analysis was done in soil chemistry and soil fertility laboratory, faculty of agriculture, Sebelas Maret University. Soil characteristics was determined in 3 stages such as before planting (initial soil), at the time of maximum vegetative and harvest phase.

The research was conducted using Randomized Complete Block Design with single factor, that is combination of ameliorants (quail manure, zeolites and rock phosphate). There are 9 treatments including control treatment; P0: Control; P1: rock phosphate 2.5 t.ha<sup>-1</sup>; quail manure 5 t.ha<sup>-1</sup>; P2: zeolite 2.5 t.ha<sup>-1</sup>; quail manure 5 t.ha<sup>-1</sup>; P3: rock

phosphate 2.5 t.ha<sup>-1</sup>; zeolite 2.5 t.ha<sup>-1</sup>; quail manure 5 t.ha<sup>-1</sup>; P4: rock phosphate 2.5 t.ha<sup>-1</sup>; quail manure 2.5 t.ha<sup>-1</sup>; P5: Zeolite 2.5 t.ha<sup>-1</sup>; quail manure 2.5 t.ha<sup>-1</sup>; P6: rock phosphate 5 t.ha<sup>-1</sup>; quail manure 2.5 t.ha<sup>-1</sup>; P7: Zeolite 5 t.ha<sup>-1</sup>; quail manure 2.5 t.ha<sup>-1</sup> and P8: rock phosphate 5 t.ha<sup>-1</sup>; zeolite 5 t.ha<sup>-1</sup>; quail manure 5 t.ha<sup>-1</sup>.

Each treatment was replicated thrice so that 27 experimental units were obtained. The cultivar Dega 1 variety was used as test crop. Soybean was planted with inter-row and intra-row spacing 25x25 cm. The experiment was conducted with due care in plant preparation, land preparation, initial soil sampling, application of treatments, planting, maintenance, harvesting vegetative maximum phase days and generative vegetative) and laboratory analysis.

The soil analysis under this study included: pH was determined in 1:2 w/v soil: water ratio, Bray I method was employed for initial soil available phosphorus determination and Olsen method after harvest (FAO, 2008). The yield components of soybean were recorded: numbers of total soybean pod (pods/plant), numbers of soybean pod content (pods/plant) and soybean yield (ton.ha<sup>-1</sup>). The analysis of variance, Duncan Multiple Range Test (DMRT) and Pearson correlation test were performed.

## RESULTS AND DISCUSSION

### Soil and Ameliorant Initial Analysis

The soil data (Table 1) shows that Sukosari has acid pH 4.9 (acid), C-organic 1.65% (low), organic matter 2.85% (low), base saturation 30.6% (low), total N 0.42% (medium), P available 4.67 ppm (very low), with low availability of base cations such as K, Ca, Mg and Na (Table 1).

The quality of ameliorants were measured (Table 2). C/N ratio of quail manure is 13.12 and P<sub>2</sub>O<sub>5</sub> in rock phosphate is 1.97%. Both criteria of C/N ratio and P<sub>2</sub>O<sub>5</sub> are suitable for application based on regulation of Indonesia's Ministry of Agriculture number 28. The CEC in zeolite is 128.60 me/100g (Table 2). The value has met the criteria of technical requirement of the regulation of Indonesia's Ministry of Agriculture number 70 with CEC zeolite which is at least 120 me/100g.

### Soil pH and P availability

The data in Table 3 shows that alfisols soil pH increased from its initial pH from acidic to slightly acid. The present data shows that soil pH range from 6.33 – 6.86, which suitable for soybean growth according to NCRRA (2016). Among different treatments, rock phosphate application has shown significant effect on soil pH. Soil with rock phosphate treatments (as in P1;P3;P4;P6;P8) recorded able to increase soil pH and the highest was obtained in P6 treatment up to 54.48% as compared to initial soil pH.

These findings are in agreement with the results of Maryanto and Abubakar (2010). Meanwhile, the results of this experiment showed that zeolites application as in P2, P5 and P7 was not statistically significant over control (P0), but rise in pH compared to its initial pH (Table 2). Recent study by Miller (2016) reported that pH had significant effect on availability of phosphorus. Agreeing to Miller's findings, the results showed that the soil pH under the P6 (rock phosphate 5 t.ha<sup>-1</sup>; quail manure 2.5 t.ha<sup>-1</sup>) reaches to neutral, as well as significantly increased phosphorus availability by 108% over control (P0).

The results indicated that there is an interaction

**Table 1:** The result of initial soil analysis.

Observation Variable	Result	Unit	Rating <sup>1</sup>
pH H <sub>2</sub> O	4.6		Acid
C-organic	1.65	%	Low
Organic Material	2.85	%	Low
Base Saturation	30.6	%	Low
Total N	0.42	%	Medium
P available	4.67	Ppm	Low
K available	1.8	me/100g	Low
Ca	3.34	me/100g	Low
Mg	0.76	me/100g	Low
Na	0.21	me/100g	Low

<sup>1</sup>Rating according to FAO (2008).

**Table 2:** Results of analysis of quail manure, rock phosphate and zeolite.

Variable	Quail Manure	Rock Phosphate	Zeolite	Unit
N total	3.1	-	-	%
P <sub>2</sub> O <sub>5</sub>	1.34	-	-	8.21
K <sub>2</sub> O	1.51	-	-	%
Corganic	4.24	-	-	%
C/N ratio	13.12	-	-	%
CEC	-	-	128.60	me/100g

between quail manure and rock phosphate. Addition of organic matter (in this case quail manure) helped to hike rock phosphate efficiency. Application of organic manure together helped to increase organic carbon content and soil nutrient availability (Lakshmi *et al.*, 2011). Previous study (Alloush, 2003; Abu El-Eyoon and Abu Ed Zamin, 2018) reported using rock phosphate and manure could help solving common problem in acid soil, such as adjusting soil pH to optimum pH and increase phosphorus availability. However, dose of ameliorant (in this case quail manure or rock phosphate) have important roles, inadequate dose did not increase phosphorus availability significantly as shown on P4 treatments.

Suspected that, from previous researches (Bernardi *et al.* 2010; Allen *et al.* 1993; Ramesh *et al.* 2015), addition of zeolite was able to enhance the dissolution of the rock-phosphate. However, in this study, it was found that the addition of zeolites together with rock phosphate, or zeolite with quail manure had no significant effect. Addition of rock phosphate and zeolite together in alfisols does increase to alkaline pH (Table 2). This later created alkaline condition in the soil, potentially  $\text{Ca}^{2+}$  availability increases and bonds with P, created a calcium phosphate bond (Helget, 2016). Stated condition in soil promotes low phosphorus availability.

**Table 3:** Effect of treatments to soil pH and available P.

Treatment	pH	Available P
P0 (Control)	6,37 a	6,39a
P1	6,79 b	10,43bc
P2	6,47 a	7,70ab
P3	6,82 b	10,33bc
P4	6,73 b	6,94ab
P5	6,33 a	8,37ab
P6	6,86 b	13,30c
P7	6,42 a	6,90ab
P8	6,79 b	7,18ab

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

**Table 4:** Effects of ameliorant treatments on soybean production.

Treatments	Number of Total Soybean pods (pods/ plant)	Number of Soybean pods content (pods/ plant)	Soybean yield (ton/ha)
P0 (Control)	22 a	20 a	2.04 a
P1	46 c	44 c	3.59 b
P2	28 ab	26 ab	2.22 ab
P3	39 bc	36 bc	2.41 ab
P4	37 abc	34 bc	2.11 ab
P5	37 abc	35 bc	2.16 ab
P6	45 c	42 c	2.57 ab
P7	39 bc	36 bc	2.38 ab
P8	42 bc	39 bc	2.43 ab

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

## Soybean Production

The yield components of soybean such as numbers of total soybean pods, numbers of soybean pods and soybean yield was observed. Ameliorant combination of quail manure and rock phosphate in P1 had significant effect compared to other treatments as shown on Table 4. P1 application did increase total soybean pods and soybean pods content by 109%, compared to control (P0). Similar findings in increase of yield components of soybean was reported under P1 treatment with 3.59 t.ha<sup>-1</sup>. P1 treatment showed significantly increased soybean yield (75.9%) as against control (P0). Shinde and Hunje (2019) experiment on chickpea found that application of organic manure gave the highest 100 seed weight. This is due to organic manure ability to supply nutrients for plants. It was recorded that highest soybean production under P1 (quail manure 5 t.ha<sup>-1</sup>; rock phosphate 2.5 t.ha<sup>-1</sup>) treatment.

Regarding to available soil phosphorus (Table 3), soybean requires 0.25 – 0.50 ppm of phosphorus (Reuter and Robinson, 1986), during vegetative phase for plants growth and later on kept in form of seed/pods at generative phase (FAO, 2004). The experimental data (Table 3) showed that ameliorant treatment was able to increase phosphorus availability compare to soil without ameliorant treatment (P0). Even more, soil with ameliorant combination of rock phosphate and quail manure (P1 and P6) gave significant result.

Availability of nutrients in this case phosphorus will affect soybean production. To prove this theory, correlation test between phosphorus availability and soybean yield was analyzed. It showed that there was positive correlation between phosphorus availability and soybean yield ( $r = 0.854$ ). Devi *et.al.*, (2012) found similar result that level of phosphorus in soil determine soybean yield, regarding the importance of phosphorus for growth and nitrogen fixation. Use of zeolite in this study had no significant effect on soybean yield. Theofanoudis *et al.* (2015) tried similar experiment using manure, mineral fertilizer together with zeolite in cauliflower and reported zeolite addition had no significant effect towards cauliflower yield.

		pH		
Amelioran		N	Subset	
			1	2
Duncan <sup>a,b</sup>	P5	3	6,33	
	P0	3	6,37	
	P7	3	6,42	
	P2	3	6,47	
	P4	3		6,73
	P8	3		6,79
	P1	3		6,79
	P3	3		6,82
	P6	3		6,86
	Sig.		,241	,261

Means for groups in homogeneous subsets are displayed. Based on observed means. The error term is Mean Square(Error) = ,015.

a. Uses Harmonic Mean Sample Size = 3,000.

b. Alpha = ,05.

Phosphorus					
Ameliorant		N	Subset		
			1	2	3
Duncan <sup>a,b</sup>	P0	3	6,40		
	P7	3	6,90	6,90	
	P4	3	6,94	6,94	
	P8	3	7,19	7,19	
	P2	3	7,70	7,70	
	P5	3	8,37	8,37	
	P3	3		10,33	10,33
	P1	3		10,43	10,43
	P6	3			13,31
	Sig.		,263	,056	,081

Means for groups in homogeneous subsets are displayed. Based on observed means. The error term is Mean Square(Error) = 3,474.

a. Uses Harmonic Mean Sample Size = 3,000.

b. Alpha = ,05.

		Total Pods			
Treatment		N	Subset		
			1	2	3
Duncan <sup>a,b</sup>	P0	3	22		
	P2	3	28	28	
	P5	3	37	37	37
	P4	3	37	37	37
	P7	3		39	39
	P3	3		39	39
	P8	3		42	42
	P6	3			45
	P1	3			46
	Sig.		,050	,071	,202

Means for groups in homogeneous subsets are displayed. Based on observed means. The error term is Mean Square (Error) = 1514,479.

a. Uses Harmonic Mean Sample Size = 3,000.

b. Alpha = ,05.

		Soy Content			
Treatment		N	Subset		
			1	2	3
Duncan <sup>a,b</sup>	P0	3	20		
	P2	3	26	26	
	P4	3		34	34
	P5	3		35	35
	P3	3		36	36
	P7	3		36	36
	P8	3		39	39
	P6	3			42
	P1	3			44
	Sig.		.309	.071	.175

Means for groups in homogeneous subsets are displayed. Based on observed means. The error term is Mean Square(Error) = 54,889.

a. Uses Harmonic Mean Sample Size = 3,000.

b. Alpha = ,05.

		ton/ha		
Treatment		N	Subset	
			1	2
Duncan <sup>a,b</sup>	P0	3	2,04	
	P4	3	2,11	2,11
	P5	3	2,16	2,16
	P2	3	2,22	2,22
	P7	3	2,38	2,38
	P3	3	2,41	2,41
	P8	3	2,43	2,43
	P6	3	2,57	2,57
	P1	3		3,59
	Sig.		,465	,052

Means for groups in homogeneous subsets are displayed. Based on observed means. The error term is Mean Square (Error) = ,587.

a. Uses Harmonic Mean Sample Size = 3,000.

b. Alpha = ,05.

## CONCLUSION

The completely randomized design using soybean as test crop in alfisols with 8 treatments of blended phosphorus fertilizers showed that there is an increasing pH (54.48 %) over control under rock phosphate fertilizers. Interaction between manure and rock phosphate helped increased phosphorus availability in alfisols by 108 %. The available soil phosphorus had yielded positive correlation to soybean production ( $r=0.854$ ). Based on the result of this study, we recommend treatment P1 (quail manure 5 t.ha<sup>-1</sup> and rock phosphate 2.5 t.ha<sup>-1</sup>) because this treatment gave the highest soybean production.

## REFERENCES

- Akande MO, Adediran JA. and Oluwatoyinbo. FI., (2005). Effects of rock phosphate amended with poultry manure on soil available p and yield of maize and cowpea, African Journal of Biotechnology. 4: 444-448.

- Allen ER., Hossner LR., Ming D.W. and Henninger, D.L., (1993). Solubility and cation exchange in phosphate rock and saturated clinoptilolite mixtures, Soil Science Society of America Journal. 57:368-374.
- Alloush, G.A. (2003). Dissolution and Effectiveness of Phosphate Rock in Acidic Soil Amended with Cattle Manure. Plant and Soil. 251: 37-46.
- Bernardi, A.C.C., Monte, M.B.M., Paiva, P.R.P., Werneck, C.G., Haim, P.G. and Barros, F.D.S. (2010). Dry Matter Production and Nutrient Accumulation after Successive Crops of Lettuce, Tomato, Rice and Andropogon Grass in a Substrate with Zeolite. Revista Brasileira de Ciência do Solo. 34: 435-442.
- Bhat, J.A., Chandra, M., Mandal, B. and Hazra G.C (2017). Nature of Acidity in Alfisols, Entisols and Inceptisols in Relation to Soil Properties. Journal Communications in Soil Science and Plant Analysis. 48: 395-404.
- Devi, K.N., L. Nongdren Khomba Singh., T. Sunanda Devi., H. Nanita Devi., T. Basanta Singh., K. Khamba Singh. (2012). Response of Soybean [Glycine max (L.) Merrill] to Sources and Levels of Phosphorus. Indian Journal of Agricultural Science. 4: 45-53. ISSN 1916-9752.
- El-Eyuoon, A and Amin, A.Z. (2018). Improvement in phosphorus use efficiency of corn crop by amending the soil with sulfur and farmyard manure. Journal Soil Environ. 37: 62-67.
- Fink, J.R., A.V. Inda, Tiecher, T. and Barrón, V. (2016). Review: Iron Oxides and Organic Matter on Soil Phosphorus Availability. Journal Ciência e Agrotecnologia. 40:369-379.
- Food and Agriculture Organization. (2008). Guide Laboratory Establishment For Plant Nutrient Analysis- FAO Fertilizer and Plant Bulletin No 19. Food And Agriculture Organization of The United Nations, Rome.
- Harter, R.D. (2007). Acid Soils of The Tropics a Technical Notes. Echo, Florida USA.
- Heard, J. (2005). Nutrient Uptake and Partitioning by Soybeans in Manitoba. University of Manitoba, Canada.
- Helget, R.L. (2016). Soybean Yield and Plant Response to Phosphorus Fertilization Theses and Dissertations. South Dakota State University, USA.
- Khasawneh F. E. and E. C. Doll. (1978). The Use of Phosphate Rock for Direct Application to Soils. Advance in Agronomy vol. 30. Academic Press ISBN 012-000730-4.
- Lakshmi, Ch. S. R., Sreelatha, T., Usha Rani, T., Rao, S.R.K. and Naidu, N.V. (2011). Effect of Organic Manures On Soil Fertility and Productivity Of Sugarcane In North Coastal Zone of Andhra Pradesh. Indian J. Agric. Res. 45 (4): 307-313.
- Maryanto, J and Abubakar. (2010). Effects of Fertilizer Concentrate and Rock Phosphate in Letuce (*Lactuca sativa*) on Andisols. Journal Agrovigor. 2: 110-118.
- Miller J.O (2016). Soil pH Affects Nutrient Availability. Fact Sheet FS – 1504 Publication Series. University of Maryland Extension, USA.
- Milosevic, T., Milosevic N (2009). The effect of zeolite, organic and inorganic fertilizers on soil chemical properties, growth and biomass yield of apple trees. Plant Soil Environ. 55: 528-535.
- Monsanto Technology (2015). Importance of P and K in Corn and Soybean Development Bulletin. <http://www.asgrowandekalb.com/>[Accessed on 12/02/2019].
- Northeast Region Certified Crop Adviser (2016). Soil Fertility and Nutrient Management Study Guide. Farmington, New York.
- Pinto, F.A., E.D. de Souza, H.B. Paulino, N. Curi, M.Aurélió, C. Carneiro (2013). P-Sorption and Desorption In Savanna Brazilian Soils as a Support for Phosphorus Fertilizer Management. Ciênc. agrotec. 37: 521-530.
- Rostami G.H and A.G. Ahangar (2013). The effect of cow manure application on the Distribution Fractions of Fe, Mn and Zn in agricultural soils. IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS) 6: 60-66.
- Ramesh,K., Ashis K. B and Ashok K. Patra (2015). Zeolitic farming. Indian Journal of Agronomy. 60: 185-191.
- Reuter, D.J. and J.B. Robinson (1986). Plant Analysis: an Interpretation Manual. Inkata Press 240 p.
- Shinde, P. and Hunje, R. (2019). Influence of soil application of organic manures and foliar spray of organic nutrients on resultant seed quality in Kabuli chickpea (*Cicer arietinum* L.) varieties. Legume Research. 42: 818-823.
- Theofanoudis, S., S. Petropoulos, V. Antoniadis (2015). The Effect of Manure, Zeolite and Mineral Fertilizer on the Yield and Mineral Composition of Cauliflower. Conference Paper VI<sup>th</sup> International Agricultural Symposium, Greece.