Anjoro: International Journal of Agriculture and Business
Vol. 4 Issue 1, April 2023
p-ISSN: 2721-8678 | e-ISSN: 2721-7914. **DOI: 10.31605/anjoro.v4i1.2278**

Availability of phosphorus in Ultisols by applying compost and phosphate rock

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Received January 9th, 2023; revised April 4th, 2023; accepted April 25th, 2023

ABSTRACT

Ultisols are the largest order in Indonesia among other acid soils, namely around 41,919 million ha, with the problem of insufficient P availability in soil for plant growth, requiring special treatment to increase available P in the soil. This study aims to examine the effect of compost and rock phosphate in increasing the availability of P in Ultisols. The research was conducted in April–May 2016 at the Laboratory of Chemistry and Soil Fertility, University of Hasanuddin, Makassar. The study used a randomized block design and was carried out by incubating straw compost, gamal leaves, cow dung and rock phosphate in Ultisol Soil with a soil weight of 300 g. The research results show that 15th day of incubation showed the highest available P of 12.97 ppm with a pH of 5.15 in the KJ575%+KS525%+BF treatment, while on the 30th day of incubation the available P increased 17.45 ppm in the rock phosphate treatment with a pH of 5.58. The application of rock phosphate and SP36 reduced Al-P, Fe-P, and Ca-P, while the application of organic matter, in this case compost, did not reduce Al-P, Fe-P, and Ca-P.

Keywords:
Compost, Organic matter, Phosphate rock, Ultisols

1. Introduction

Acidic soils in Indonesia cover five orders, namely Entisols, Inceptisols, Oxisols, Spodosols, and Ultisols, covering a total area of 102,817 million hectare. Acidic soils are widespread throughout Indonesia, mainly on Kalimantan Island (39,242 million hectares), Sumatra (29,344 million hectare), Papua (17,257 million hectare), Sulawesi (9,522 million hectare), and Java Island (3,807 million hectare). Ultisols are the largest ordo among other acidic soils, around 41,919 million hectare, followed by Inceptisols with 40,879 million hectare and Oxisols with 14,134 million hectare [1].

The main constraints of acidic soils in Ultisol Soils are the low content of nutrient-carrying minerals, high Al saturation, Fe and Mn, high phosphate fixation power, low base saturation, and low levels of N and organic matter that accumulate in the surface layer of the soil [2]. The high rainfall in parts of Indonesia causes a high level of nutrient leaching, especially bases, so that the bases in the soil will soon be washed out of the soil environment, and what will remain in the adsorption complexes of clay and humus. As a result, the soil reacts acutely with low base saturation and shows high aluminum saturation [3].

Phosphorus (P) is one of the essential nutrients for plants. Plants need P to stimulate root growth, accelerate and strengthen the growth of young plants to old age, help assimilation and respiration, and accelerate flowering [4].
The amount of P in the soil is relatively small (generally less than 0.3 ppm and the movement is very slow [5]. Factors affecting P include clay mineral type, soil pH, reaction time, and dissolved Fe, Al, and Mn ions. The availability of P in the soil depends on the nature and characteristics of the soil. In acidic soils, they combine in

the form of Al-P, Fe-P and Occluded P. In alkaline soils, P is generally compounded as Ca-P [6].

A low pH value in the soil causes an increase in P adsorption because a decrease in pH results in the activation of Al on the surface of colloidal inorganic minerals. The adsorption of phosphate anions also increased with an increasing degree of soil weathering. This is probably due to the increased Al content. The balance between P-labile and P-absorbed is also disturbed, as P moves slowly from P-stable to P-labile [7]. Efforts have been made to improve the soil properties of Ultisols by liming to increase the soil pH, adding organic matter to improve the physical, chemical, and biological properties of the soil, and fertilization to provide macronutrients such as phosphorus [8].

The application of organic matter to soils that are low in nutrient content is known to be able to suppress the solubility of Al and Fe and can reduce the amount of adsorbed P. This was due to the presence of organic acids produced during the decomposition process in the form of organic anions. Organic anions have the property of being able to bind free Al and Fe in solution. Thus, the concentration of free Al and Fe in the solution will decrease, and it is hoped that more available phosphate will be available [9].

Based on existing problems and the importance of P nutrients for plants, this study was conducted using compost from rice straw, *gamal* leaves, and cow menure incubated with rock phosphate, which is expected to increase available P in acidic soils (Ultisols).

2. Methods

Soil sampling was carried out in the plantation area, Moncongloe District, Maros Regency, South Sulawesi at the coordinates: 05° 08' 55.13" South Latitude and 119° 33' 54.02" East Longitude. This study was conducted from April to May 2016 at the Soil Fertility Chemistry Laboratory, Hasanuddin University. This study used a randomized block design and was carried out by incubating straw compost, *gamal* leaves, cow menure and rock phosphate in Ultisol Soil with a soil weight of 300 g.
The treatment was repeated three times with three controls so that the total number of soil samples was 21 experimental units.
The parameters observed were P (available), P-total, pH, Al-P, Fe-P, and Ca-P.
The description of the treatment in this study is as follows:

- Straw 100% (0.75 g) equivalent to 5 $t.ha^{-1}$ + rock phosphate (0.07 g) equivalent to 468.16 $kg.ha^{-1}$
- Straw 75% + gamal 25% (0.75 g) equivalent to 5 $t.ha^{-1}$ + rock phosphate (0.07 g) equivalent to 468.16 $kg.ha^{-1}$
- Straw 75% + 25% (0.75 g) cow menure equivalent to 5 $t.ha^{-1}$ + rock phosphate (0.07 g) equivalent to 468.16 $kg.ha^{-1}$
- Straw 100% (1.5 g) equivalent to 10 $t.ha^{-1}$ + rock phosphate (0.07 g) equivalent to 468,16 $kg.ha^{-1}$
- Straw 75% + gamal 25% (1.5 g) equivalent to 10,000 $kg.ha^{-1}$ + rock phosphate (0.07 g) equivalent to 468,16 $kg.ha^{-1}$
- Straw 75% + cow dung 25% (1.5 g) equivalent to 10,000 $kg.ha^{-1}$ + rock phosphate (0.07 g) equivalent to 468.16 $kg.ha^{-1}$

- Without organic matter + rock phosphate (0.07g) equivalent to 468.16 kg.ha^{-1}
- Without organic matter + SP36 (0.042 g).

3. Results and Discussion

3.1. Results of Preliminary Analysis of Ultisol Soil

Based on the soil sample results at the Soil Chemistry and Physics Laboratory, Department of Soil Science, Hasanuddin University, the initial analysis of Ultisol Soil are shown in Table 1.

Ta**ble 1. Results of the initial analysis of Ultisol Soil**

Parameter	Unit	Results*	Criteria
pH (H_2O)	Ratio 1: 2.5	5.0	Sour
C	%	1.36	Low
N	%	0.12	Low
P_2O_5–Bray	mg.kg^{-1}	8.65	Very low
P_2O_5HCl	mg.kg^{-1}	21.65	Currently
CEC	cmol(+).kg^{-1}	20.46	Currently
ca	cmol(+).kg^{-1}	4.26	Low
Mg	cmol(+).kg^{-1}	1.32	Currently
K	cmol(+).kg^{-1}	0.81	Tall
Na	cmol(+).kg^{-1}	0.32	Low
Al-P	ppm	15.80	
Fe-P	ppm	31.35	
Stamp	ppm	29	
Texture	-	Clay Loam	-

*Results of analysis at the Soil Chemistry and Physics Laboratory, Department of Soil Science, Faculty of Agriculture, Hasanuddin University, 2016.

From the results of the initial soil analysis shown in the table above the texture of dusty clay loam soil with low total N content (0.12%), low organic C (1.36%), acid pH (5.0), very low available P (8.65 mg.kg^{-1} while CEC was moderate (20.46 cmol(+).kg^{-1}). In Table 1, the low total N-value and available P are also affected by low organic matter, so the soil becomes acidic and causes soil fertility problems.

3.2. Availability of P and P Fraction in Ultisol Soil after 15 Days of Incubation

The results of the analysis of the availability and P fraction of Ultisol Soil after 15 days of incubation are shown in Table 2. Table 2 shows that available P levels increased in all treatments, which was in line with the increase in soil pH. All treatments showed significant interactions with available P on the 15th day of incubation. The table also shows an increase in the P fraction fixed by Al, Fe, and Ca in Al-P, Fe-P, and Ca-P forms . On the 15th day of incubation, the KJG5+BF treatment significantly effected on Al-P and Fe-P, whereas the KJS10+BF treatment had a significant effect on Fe-P.

Table 2. Results of sample analysis treated with straw, gamal, cow menure, and rock phosphate from Ultisol Soil after 15 days of incubation.

Treatment	P Available (ppm)	Al-P	Fe-P	Stamp	pH
KJ5 + BF	9.19	34.76 c	85.31 f	57.45 ab	5.18
KJG5+BF	11.79	39.99 d	90.76 g	72.39 cde	5.15
KJS5+BF	12.97	35.98 cde	71.43 d	64.00 bc	5.15
KJ10 + BF	11.79	33.70 bc	82.60 e	78.07 d	5.17
KJG10+BF	9.90	37.98 cde	62.44 c	78.41 d	5.10
KJS10+BF	9,19	38.33 cde	80.68 e	80.25 d	5.11
BF	11.55	29.08 ab	52.91 a	56.32 ab	5.11
SP36	10,14	25.15 a	57.23 b	54.36 a	5.13

Note: Numbers followed by letters that are not the same indicate significant differences.

3.3. Availability of P and P Fraction in Ultisols after 30 Days of Incubation

The results of the analysis of the availability and P fraction of Ultisol Soil after 30 d of incubation are shown in Table 3.

Table 3. Results of sample analysis treated with straw, gamal, cow menure, and rock phosphate from Ultisol Soil after 30 days of incubation

Treatment	P Available (ppm)	Al-P	Fe-P	Stamp	pH
KJ5+ BF	15.80	46.36 c	49.86 a	70.20 b	5.18
KJG5+BF	12.50	47.06 c	90.73 d	77.63 c	5.35
KJS5+BF	12,26	34.18 b	55.01 ab	70.99 b	5.30
KJ10 + BF	13,20	45.84 c	83.56 d	75.18 bc	5.55
KJG10+BF	16.03	47.07 c	68.55 c	79.37 c	5.5
KJS10+BF	15.09	45.93 c	63.57 bc	71.43 b	5.27
BF	17.45	29.20 a	43.74 a	54.35 a	5.58
SP36	16,74	34.18 b	46.10 a	53.70 a	5.25

Note: Numbers followed by letters that are not the same indicate significant differences.

Table 3 shows that the available P levels increased in all treatments, in line with the increase in soil pH. All treatments showed significant interactions with available P on the 30th day of the incubation. The increase in available P, namely rock phosphate, was highest in the treatment after 30 days of incubation, which was significantly different from the other treatments. This is since the acidic pH can accelerate the dissolution of rock phosphate to become available in the soil. The table also shows an increase in the P fraction fixed by Al and Ca in the form of Al-P and Ca-P. On the 30th day of incubation, a decrease in the P fraction was fixed by Fe in the form of Fe-P.

3.4. Discussion

Based on the initial analysis of Ultisol Soil at the Soil Chemistry and Physics Laboratory, the initial pH of the Ultisol Soil was 5.0, which was included in the acid criteria. This is in accordance with the opinion of [10], where the acidity of Ultisol Soil was less than 5.5. Some research results that experts have conducted indicate that the application of organic matter can add nutrients, inhibit soil moisture evaporation, and reduce soil acidity.

In the results of the initial analysis, the value of P_2O_5 (ppm P) was 8.65, N (%) was 0.12, and it had an organic C content (%) of 1.36, which was classified in the low category. The presence of organic matter in the soil was increased to reduce the existing constrains on Ultisols. In addition to supplying organic matter, organic matter can also improve soil structural properties and increase CEC and soil productivity [11]. As shown in Table 1, a low N content was obtained, related to the low organic matter content [4], in which the low total N content in each Ultisol subgroup was due to the low soil organic C content, loss due to washing, evaporation into the air, and harvest transport.

The results of exchangeable base values in the initial analysis of Ultisol Soil obtained the results, namely the value of K (cmol(+).kg^{-1}) of 0.81, the value of Na (cmol(+).kg^{-1}) of 0.32, the value of Mg (cmol(+).kg^{-1}) of 1.32 and the value of Ca (cmol(+).kg^{-1}) of 4.26. while the CEC value obtained was 20.46, which was classified as low. In accordance with the opinion of [12], Ultisol Soil is poor in nutrients, especially P and exchangeable cations such as Ca, Mg, Na, and K, high Al content, (CEC) low cation exchange capacity, and sensitive to erosion.

From the statistical test results in Table 2, the highest available P after 15 d of incubation was in the KJS5+BF treatment at 12.97 ppm. According to [13], the results of his research stated that the application of organic matter (green manure, manure and straw) can increase soil pH, available P, total N, CEC, K-dd and reduce Al-dd, P absorption, Al and Fe fractions in the soil, so as to increase the P content of plants, in the end crop yields also increase. However, the lowest available P was obtained in the KJS10+BF and KJ5+BF P treatments, namely 9.19 ppm. The low available P was caused by the absorption of P by Fe and Al to form Fe-P and Al-P.

Table 2 also shows the highest pH value (5.18 in the KJ5+BF treatment with an available P value of 9.19 ppm which is still low, in accordance with the opinion [14] that the contents of nutrients such as N, P, K, and Ca were generally low, with a very low pH of 4-5.5. Although there was an increase in available P after 15 d of incubation, a relatively small increase in P occurred. This is because P is fixed in the form of Al-P, Fe-P, and Ca-P, which are difficult to dissolve. This is in accordance with the opinion of [15], which states that the longer P is in contact with the soil, the more P is fixed so that Al-P and Fe-P are formed, which are difficult to dissolve and are occluded (surrounded by P).

After 15 days of incubation in Table 2, the highest Al-P value was in the KJG5+BF treatment, which was 39.99 ppm, which was significantly different from the KJ5+BF treatment and the KJ10+BF treatment, which were respectively 34.76 ppm and 33.70 ppm and respectively. ppm in the SP-36 treatment, namely 25.15 ppm. It can also be seen that the highest Fe-P was in the KJG5+ BF treatment, which was 90.76 ppm and was very significantly different in the phosphate rock treatment and the SP36 treatment, which were 52.91 ppm and 57.23 ppm, respectively. The highest Ca-P was observed in the KJS10+BF treatment, which was 80.25 ppm, significantly different from that of the SP36 treatment, which was 54.36 ppm. As shown in Table 2, the ability of Fe to bind P is greater than that of Al and Ca.

From the statistical test results in Table 3, the highest available P after 30 d of incubation was in the Phosphate Rock treatment at 17.45 ppm, and the lowest was in the KJS5+BF treatment at 12.26 ppm. After 30 days of incubation, there was an increase in P-available in all treatments. Thus, all treatments affected the available P in the soil. The increase in available P, namely rock phosphate, was highest in the treatment after 30 days of incubation, which was significantly different from the other treatments. This is since the acidic pH can accelerate the dissolution of rock phosphate to become available in the soil. This is in line with the opinion of [16], which states that the change in P is mainly regulated by pH if an acidic pH can accelerate the weathering of the P fraction into the available P form.

After 30 days of incubation in Table 3, the highest Al-P value was in the KJG10+BF treatment, namely 47.07 ppm, which was significantly different from the KJG5+BF treatment and the SP-36 treatment, each of which was 34.18 ppm and significantly different in the Phosphate Rock treatment. ppm, which is equal to 29.20 ppm. It can also be seen that the highest Fe-P was in the KJG5+BF treatment which was 90.73 ppm and was significantly different in the phosphate rock treatment and the SP36 treatment which were 43.74 ppm and 46.10 ppm respectively. Meanwhile, the highest Ca-P was in the KJG10+BF treatment, which was 79.37 ppm, which was significantly different from that of the Phosphate Rock and SP-36 treatments (54.36 ppm and 53.70 ppm, respectively). Table 4 shows a decrease in the P fraction fixed by Fe in the form of Fe-P.

The decrease in the Fe-P fraction due to the addition of organic matter in each treatment was caused by a chelating reaction between the organic acid groups from straw, cow dung, gamal, and rock phosphate with Fe. This is explained by the results of [17] that organic acids (oxalic acid, citric acid, and malic acid) excreted from phosphate-dissolving bacteria can form organic metal complexes by releasing Fe-P bonds. Furthermore, it was also explained that organic ligands bind to metal cations through functional groups such as the carboxylic groups of their organic acids to form a ring called a chelate.

As shown in Table 3, the decrease in the Fe-P fraction was due to the addition of P from the organic materials. The addition of P to the soil can increase Fe-P and Al-P which then decreases because Al-P and Fe-P become veiled P. Phosphate ions that are added to the soil initially react quickly with soil components, which then slows down [18]. As there was only a decrease in the Fe-P fraction without a decrease in Al-P, the P released from Fe was partly bound by Al and partly became available P and changed into the form of the Ca-P fraction.

4. Conclusion

Based on the results of this research that has been done, it can be concluded that overall incubation 15 and 30 days showed an increase in available P, which in each treatment with a pH value that also increased. The highest increase in available P was in the rock phosphate treatment which was influenced by an acidic pH so that it accelerated the dissolution of phosphate to become available from the P fraction to available P.

Acknowledgements

The authors thank for the assistance or encouragement of colleagues, especially the work of technical staff and the Soil Science Department of Hasanuddin University.

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