

# Soil Fertility Status, Nutrient Uptake, and Maize (*Zea mays* L.) Yield Following Organic Matters and P Fertilizer Application on Andisol

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**Abstract.** Objective of this study were to elucidate effects of organic matters and P fertilizer application on soil fertility status, nutrient uptake and maize yield in the Andisol. This experiment consisted of two factors. The first factor comprised of four levels of organic matters input (without organic matter, manure, rice straw, and *Gliricidia sepium* leaves), with the application dosage 10 t.ha<sup>-1</sup> and the second factor comprised of three levels of P fertilizer application (without P addition (control), 50 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup>, 100 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup>). Results of this study showed that organic matters and P fertilizer application improved soil fertility status, especially pH, soil organic C, cation exchange capacity (CEC), available P which resulted in an increase in P uptake that improve yield of maize. The highest yield of maize (corn cob) was obtained through application *Gliricida sepium* (8.40 t.ha<sup>-1</sup>), followed by manure (6.02 t.ha<sup>-1</sup>) and rice straw (5.87 t.ha<sup>-1</sup>). Application of 50 kg P<sub>2</sub>O<sub>5</sub> Ha<sup>-1</sup> yield was (5.76 t.ha<sup>-1</sup>) and application of 100 Kg P<sub>2</sub>O<sub>5</sub> Ha<sup>-1</sup> yield was (6.12 t.ha<sup>-1</sup>).

## 1. Introduction

The one type of land troubled by the presence of phosphate is Andisol [1][2]. Andisol actually have a relatively high content of total P 160-500 mg.100 g<sup>-1</sup> soil, but the number of P available to plants is very low, only about 1% of the total P contained in the soil [2][3]. As the third after water and nitrogen, the element P is estimated to be limiting growth and crop production [3]. P inorganic fertilizer application to increase the availability of P that can be utilized by plants, it is less efficient, since only 8-13% are available and can be absorbed by plants, the rest is converted into a form insoluble phosphate compounds and unavailable to plants [4][5].

Organic matter, is one effort that can be done because it can increase the availability of soil P [6][7][8][9]. The use of organic matter (manure, mulch and compost) has been shown to increase soil fertility [10]. Some research indicates the real role of organic matter in improving the availability of P in Andisol [11]. Susilowati [12] reported that organic matter in the form of *Gliricida sepium*, *Leucaena glauca* and *Zea mays* in Andisol very markedly increase the availability of P after incubation of 30 days and 60 days. Research conducted Safitri [13] showed that the use of organic materials such as prunings *Tithonia* and *Tephrosia* in Andisol able to increase the availability of P. Increased availability of P as a result of organic matter can occur because during the process of decomposition of organic materials produce dissolved organic acids such as citric acid, malic acid, and



acetic acid which plays an important role in the binding of Al and Fe that P became available [14][15][16]. Okajima [17] and Bell and Beessho [18] said that the use of organic materials is based on the assumption of the role of humic acid and fulvic relation to its ability to reduce the occurrence of bond between phosphorus and aluminum or iron in the soil. Andisol in the area of Tawangmangu, Central Java, Indonesia (study site), cow manure, rice straw and crop plants *Gliricidia sepium* is common and has been used by farmers since availability is quite a lot. This research aims to exploit the potential of organic matter (manure, rice straw and *Gliricidia sepium*) and P fertilizer to improve soil fertility in providing Andisol P element on the corn crop.

## 2. Experimental

A field experiment was conducted in experimental station Seed Food Crops and Horticulture, Tawangmangu, Karanganyar, Central Java, Indonesia. The soil type Andisol with loam texture (45% sand, clay 16% and silt 39%), pH H<sub>2</sub>O (5.6), high soil organic matter (4.96%) and nutrient P-available is very low (3.49 mg.kg<sup>-1</sup>) and a high CEC (32.15 mg.kg<sup>-1</sup>). The organic material used is manure, rice straw and *Gliricidia sepium* and seed corn (*Zea mays* L.). In addition, to use of urea and KCl fertilizers, also used pesticides to control pests and diseases that arise during the course of the study in the field.

This study was conducted using factorial trial with two factors conducted on the experimental plot size of 3 x 1.5 m. The first factor was the kind of organic material (10 t.ha<sup>-1</sup>), which consists of four levels, ie, without organic matter (B0), manure (B1), the provision of rice straw (B2) and *Gliricidia sepium* (B3), The second factor was the provision SP36 which consists of three levels, namely without fertilizer P (P0), 50 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> (P1) and P<sub>2</sub>O<sub>5</sub> 100 kg.ha<sup>-1</sup> (P2). Twelve treatments combination were set out in a randomized block design with three replications. At each treatment was given basic fertilizer urea (300 kg.ha<sup>-1</sup>) and KCl (50 kg.ha<sup>-1</sup>) as a basal fertilizer.

Variable corn growth observed absorption P (calculated by multiplying the dry biomass of the top with a concentration of P-plant tissue) and corn yields are expressed in weight of corn cobs per plot at the end of the experiment. For soil analysis conducted on P-available (extracted by the method of Bray-II) and P-total (extract H<sub>2</sub>SO<sub>4</sub> 1M), soil pH (in 1: 2.5 ratio of soil: water), soil organic matter (method of Walkley and Black), CEC (using ammonium acetate at pH 7.0), carried out the beginning and end of the experiment. The data were then analyzed statistic. The results of the analysis are presented in Table ANOVA on a real level (5%) and highly significant (1%). To distinguish between the mean treatments used multiple range test Duncan Multiple Range Test (DMRT).

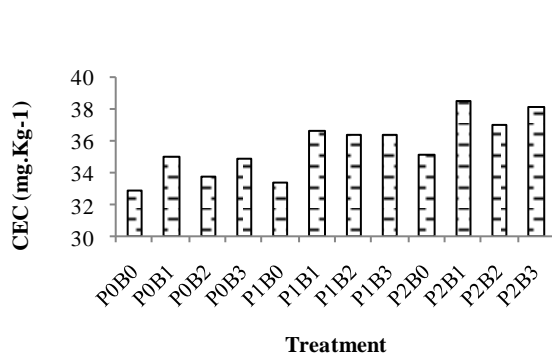
## 3. Results and Discussion

From an initial analysis of the soil chemical properties Andisol with criteria according [4], especially slightly acid pH H<sub>2</sub>O (5.6), NaF pH (11.1), soil organic matter (4.96%), P-available nutrients is very low (3.49 mg.Kg<sup>-1</sup>) and a high CEC (32.15 mg.Kg<sup>-1</sup>). Referring to the key guidelines for the estimation of the suitability of land especially soil fertility (pH, CEC, BS, SOM and available P) the fertility of the soil include the category of low to moderate [4]. The low nutrients available P can be a major limiting nutrient in plant growth that is less favorable for crops [19][3]. Organic matter is an effort to increase the availability of P that can be utilized by plants [6]. Characteristics of organic materials used in this study, are presented in Table 1,

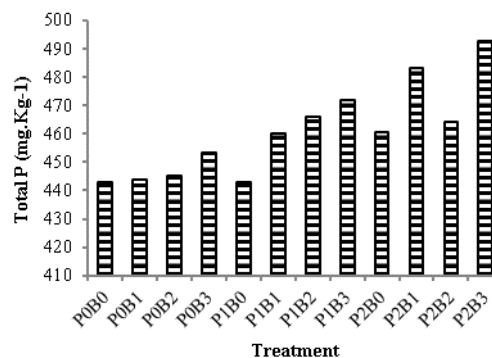
**Table 1.** Characteristics of organic materials

Characteristics of organic materials	Manure	Rice straw	<i>Gliricidia sepium</i>
Organic C (%)	29.90	43.44	46.11
Total N(%)	0.67	0.85	2.28
Total P (%)	0.22	0.36	0.61
Ratio C/N	43.97	50.49	20.12
Ratio C/P	130.03	117.42	74.37
Total organic acid (%)	21.56	26.91	35.53
Humic acid (%)	16.71	15.92	22.17
Fulvic acid (%)	3.22	7.70	8.10

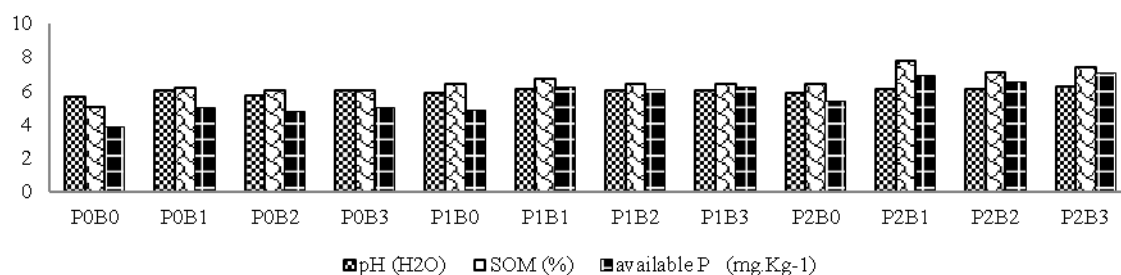
The use of organic materials was able to improve soil fertility all parameters (pH, CEC, SOM and P), as presented in (Table 2) and (Figure, 1,2 and 3). Increased pH ( $H_2O$ ) as a result of the provision of the three kinds of organic materials, the highest row in the treatment of *Gliricidia sepium*, manure and rice straw. P fertilizer treatment, achieved at the highest dose of  $100 \text{ kg ha}^{-1} \text{ P}_2\text{O}_5$  followed by  $50 \text{ kg ha}^{-1}$ .



**Figure 1.** Effect of treatment on CEC



**Figure 2.** Effect of treatment on Total P



**Figure 3.** Effect of treatment on pH, soil organic matter (SOM), available P

Description:

P0 = without P fertilizer, P1 = P fertilizer dose of  $50 \text{ Kg.Ha}^{-1}$ , P2 = P fertilizer dose of  $100 \text{ Kg.Ha}^{-1}$ .

B0 = without OM, B1 = manure, B2 = rice straw and B3 = *Gliricidia sepium*

Increased pH ( $H_2O$ ) in the combination treatment achieved the highest *Gliricidia sepium* and P fertilizer dose of  $100 \text{ kg ha}^{-1}$  (P2B3) of 5.66 to 6.25, an increase of approximately 10%. The rising trend pH ( $H_2O$ ) very likely caused by the ligand exchange reactions between organic anions decomposition of organic matter, especially humic and fulvic acids to the free -OH on local exchanges, so the effect on improvement of OH ions in the soil solution [20][15][21]. Bell and Beessho [18] says that the role of organic acids such as humic acid and fulvic, in reducing the bond between phosphorus and aluminum or iron in the soil. The humic acid and fulvic has high capability in forming a chelate with several cations, especially aluminum and iron was decreased activeness in adsorb P [9], this situation will affect the availability of P [22][23][10].

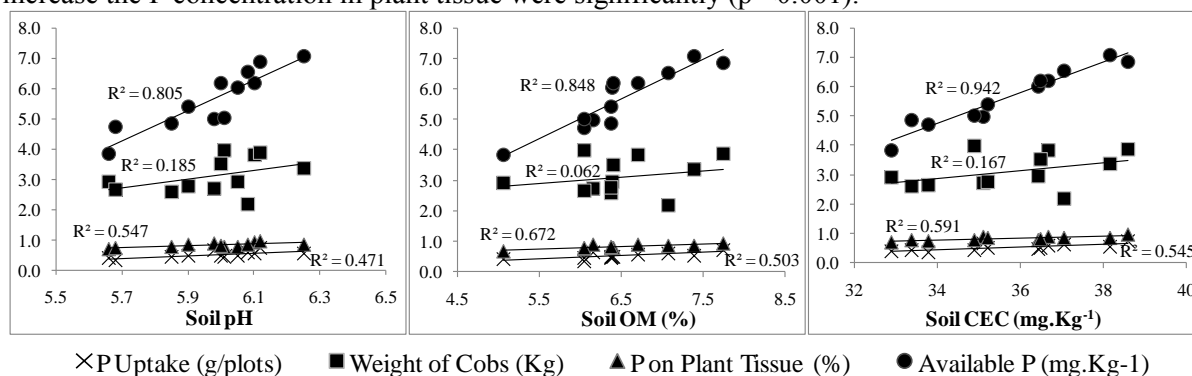
Increased P-provided may occur due to the release of P from organic materials are added, as well as the indirect influence of the organic material present in the P sorption complex of soil. The organic material is known to reduce the P sorption by iron oxides and Al, and also colloidal clay contained in the soil [14][15][16][18]. Agree with [18] and [21], humic acid content (22.17%) and fulvic acid (8.10%) higher than *Gliricidia sepium* than organic materials others (Table 1), are believed to play a role in increasing the pH ( $H_2O$ ) which in turn will positively affect the availability of P in the soil. The provision of real-P and organic materials potential in improving P and P available, which is a growth limiting nutrient corn plant other than N, K and soil organic matter [23]. Increased P-provided by a third use of organic materials in this study, in order are *Gliricidia sepium* > manure > rice straw, which is thought to be caused by the activity of organic acids, especially humic and fulvic acids. Increased P

provided the highest achieved in the combination treatment of *Gliricidia sepium* and P fertilizer dose of 100 kg.ha<sup>-1</sup> (P2B3) from 3.83 mg.kg<sup>-1</sup> to 7.06 mg.kg<sup>-1</sup> or an increase of approximately 45%. (Table 2).

**Table 2.** Characteristics of Andisol after being treated with the organic material and P fertilizer.

No.	Treatment	pH (H <sub>2</sub> O)	pH (NaF)	SOM (%)	CEC (mg.Kg <sup>-1</sup> )	available P (mg.Kg <sup>-1</sup> )	Total P (mg.Kg <sup>-1</sup> )
1	P0B0	5.66	10.39	5.05	32.88	3.83	443.14
2	P0B1	5.98	10.16	6.15	35.11	4.98	444.01
3	P0B2	5.68	10.34	6.04	33.78	4.72	445.17
4	P0B3	6.01	10.30	6.05	34.88	5.02	453.31
5	P1B0	5.85	10.40	6.38	33.38	4.85	442.96
6	P1B1	6.10	10.41	6.71	36.67	6.19	460.33
7	P1B2	6.05	10.35	6.39	36.44	6.02	466.12
8	P1B3	6.00	10.42	6.40	36.49	6.19	472.08
9	P2B0	5.90	10.49	6.38	35.22	5.40	460.48
10	P2B1	6.12	10.59	7.74	38.60	6.86	483.31
11	P2B2	6.08	10.38	7.07	37.05	6.53	464.36
12	P2B3	6.25	10.43	7.39	38.16	7.06	492.59

From the analysis of the soil at the end of the experiment (Table 2), suggesting the provision of three kinds of organic matter and fertilizer P, affecting the changes in soil properties associated with the availability of P in the soil, especially pH (H<sub>2</sub>O), CEC and SOM (Figure 4). Correlation test results showed that the pH (H<sub>2</sub>O), the Commission and SOM positively correlated with P-available ( $r = 0.821$ ,  $r = 0.967$  and  $r = 0.915$ ), which gives the sense that an increase in pH (H<sub>2</sub>O), CEC, and OM will be followed by an increase P-available. The changes P increased availability will result in an increase in the value of P uptake and P concentration in plant tissue. The results showed that the use of three kinds of organic materials (B1, B2 and B3) and fertilizer P (P1 and P2). Overall also been proven to increase the P concentration in plant tissue were significantly ( $p < 0.001$ ).



**Figure 4.** The effect of soil pH, soil organic matters, and soil CEC on P uptake, weight of Obs (maize yield), P on plant tissue, P available improvement.

The increase in P uptake of plants is determined by the concentration of P in the soil as well as the ability of plants to absorb elements of P in the soil. Where organic matter serves to meet the needs of plant nutrients that allow the plant to grow and develop properly. P is required for root development. Rooting more developed will allow for more nutrient absorption. Clarified by Foth [20], P uptake of plants is largely determined by the contact with the roots of P, P concentration in soil solution and the ability of the plant. As reported Darman [10] that the availability of P will increase P uptake which in turn affects the increase in plant dry weight and yield of corn (Table 3) and (Figure 5 and 6). P fertilizer is needed in a corn plant growth and yield [24] [25] [26].

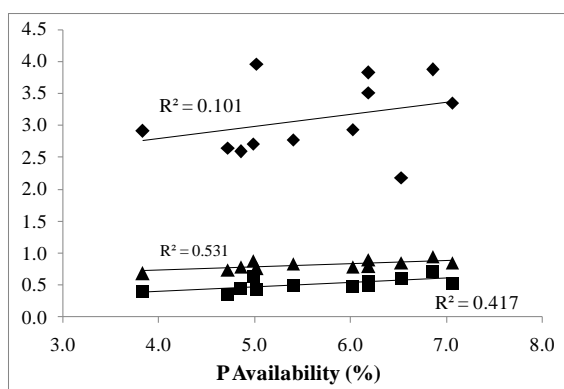
**Table 3.** Effect of organic matter and fertilizer P to shoot dry weights (g), of P plant tissue (%), P uptake (g) and the weight of cobs per plot (Kg)

No	Treatment	Shoot dry weights (g)	P on plant tissue (%)	P Uptake (g)	Weight of cobs (Kg)
1	P0B0	58.23	0.68	0.40	2.91
2	P0B1	72.77	0.88	0.64	2.71
3	P0B2	47.00	0.74	0.34	2.64
4	P0B3	56.54	0.76	0.43	3.96
5	P1B0	55.99	0.78	0.44	2.59
6	P1B1	61.88	0.90	0.56	3.82
7	P1B2	60.95	0.78	0.48	2.93
8	P1B3	61.52	0.79	0.49	3.51
9	P2B0	58.81	0.83	0.49	2.77
10	P2B1	76.62	0.94	0.72	3.87
11	P2B2	71.01	0.85	0.60	2.18
12	P2B3	62.08	0.85	0.53	3.35

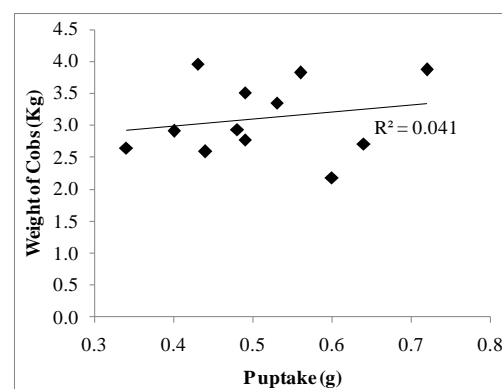
Description:

P0 = without P fertilizer, P1 = P fertilizer dose of 50 Kg.Ha<sup>-1</sup>, P2 = P fertilizer dose of 100 Kg.Ha<sup>-1</sup>.

B0 = without OM, B1 = manure, B2 = rice straw and B3 = *Gliricidia sepium*



◆ Weight of Cobs (Kg) ■ Puptake (g/plots) ▲ P on Plant Tissue (%)

**Figure 5.** The effect of P availability on weight of cobs, P uptake, P on plant tissue**Figure 6.** The effect of P uptake on weights of the cobs .

#### 4. Conclusion

Overall, this study proves that the organic material and P fertilizers can improve soil fertility and yield of corn in Andisol. Improving the status of soil fertility and yield of corn, mainly due to the effect of treatment than the use of organic materials with the addition of P fertilizer treatment, while their interaction is limited to the results of this trial was not yet able to provide increased yield of corn. Successive loss results obtained on providing the highest cob *Gliricida sepium* (8.40 t.ha<sup>-1</sup>) > Manure (6.02 t.ha<sup>-1</sup>) > Rice straw (5.87 t.ha<sup>-1</sup>). Application of 50 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> yield was (5.76 t.ha<sup>-1</sup>) and application of 100 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> yield was (6.12 t.ha<sup>-1</sup>).

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