Correlation study of soil test on phosphorus in ultisol soil for shallots (*Allium ascalonicum* L.)

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Abstract. The research objective was to determine the best soil P extraction method for shallot plants in Ultisols. This study used a single location approach. The selected location was in Kentrong village, Malangsari Village, Cipanas, Lebak, Banten Province. The research was conducted from March 2015 to May 2016, consisting of two stages, namely the creation of P nutrient status and correlation testing through planting in polybags in a greenhouse. Preparation of soil P nutrient status using phosphoric acid (H₃PO₄) from very low to very high (0X, 1/4X, 1/2X, 3/4X, and X), where X is half of the maximum absorption of 1033.3 kg P ha⁻¹. Fertilizer P was incubated for three months, then taking soil samples in each plot for analysis of soil P content. Soil P content analysis used five different extraction methods, namely Bray I (0.025 N HCl + 0.03 N NH₄F solution), Bray II (NH₄F 0.03 N + HCl 0.10 N), Mehlich I (0.0125 M H₂SO₄ + 0.05 M HCl), Morgan Wolf (Na₂C₂H₃O₂·3H₂O; pH 4.8), and Truog (0.02 N H₂SO₄ + (NH₄)₂SO₄). The planting of shallots in polybags was carried out in the greenhouse of Jakarta Assessment Institute for Agricultural Technology, using a completely randomized design (CRD), with five replications. The results showed that the best soil P nutrient extraction method for shallot plants in Ultisols was the Truog method with a correlation coefficient of 0.77 and 0.84 for the correlation between soil P content and relative yields of plant dry weight and the correlation between soil P content and Uptake P. The results of this study can be used to determine recommendations for P fertilization on shallots in an Ultisol soil.

1. Introduction

Shallot (*Allium ascalonicum* L.) is one of horticultural commodities containing nutrients and a compound called Allicin. It gives benefits in improving and maintaining body health, and has a distinctive aroma as a food flavoring. The Ministry of Agriculture is established as the priority commodity because of several reasons such as reducing dependence on imports, the high demand for these commodities, the vulnerability of these commodities to weather changes, have very high price fluctuations, and greatly affect inflation.

In Indonesia, Shallot producing-centers are in Brebes, Majalengka, Nganjuk, Probolinggo, Bima, and Cirebon. The shallot producing-center areas are dominated by Grumusol soil types. —Grumusol soil type has a relatively small distribution, which is around 2.1 million ha [13]. On the other hand, Grumusol is widely used by farmers as land for cultivating other commodities, so there will be competition in usage of this soil. The other obstacles include land degradation as a result of the use of excessive chemical fertilizer input which will have an impact on shallot yields. Based on these facts, it is necessary to expand the center of shallot cultivation by utilizing sub-optimal lands, including ultisol soil. [9] and [5], reported that ultisol in Indonesia occupies the largest area after inceptisol and still has not been widely used for agriculture. The distribution of Ultisol land is very wide, around 45.8 million ha (around
24.3%) of the total land area of Indonesia, which is spread mainly in Java, Sumatra, Kalimantan, Sulawesi and Papua [12].

Recommendations of fertilization through soil testing for food crops have been widely implemented, but the recommendation for horticultural crops, especially vegetables, has not been widely implemented. Nowadays, there have been several research results of fertilization recommendations for horticultural crops, but they are still limited. Some of the results include the recommendations for P and K on tomatoes in Inceptisol soil [6]. Other research results are recommendations for P and K on red chilies in Inceptisol soil in West Papua [1].

The developing shallot cultivation in sub-optimal land has been started. Some of the results of research on the development of shallots in sub-optimal land include peatlands, sandy soil, coastal areas and upland. Shallots planted on peatlands have a productivity of 11.13 tons ha$^{-1}$, while on sandy soils are 7.93 tons ha$^{-1}$ [3]. Meanwhile, several results of research that have been carried out on Ultisol soil include the application of K significantly increasing the yield of dry soybean in Ultisol soil [9], the monoculture system of corn cultivation accompanied by the provision of P has been able to improve the chemical properties of Ultisol soil [15]. The description above provides a considerable opportunity in the development of shallot cultivation in Ultisol soil, as long as the soil and plant management are carried out properly.

Cultivation technique in Ultisol soil must consider the characteristics of its fertility level. Therefore, it is important to make a local-specific fertilizer recommendation for shallot in Ultisol soil through a soil testing. The objective of the study was to determine the best P extraction method for ultisol soil to be used as the basis the recommendation for shallot P fertilization in ultisol soil.

2. Material and Method
The study was carried out in March 2015 - May 2016 using a single location approach which consisted of two stages. The research stages were (a) making P nutrient status in the field and (b) correlation test of P in the plastic house. The preparation of P nutrient status was carried out in the soil laboratory of Indonesian Soil Research Institute, Ministry of Agriculture and the laboratory of the Department of Soil and Land Resources, Faculty of Agriculture, IPB University.

The materials used in this study were Bima Brebes shallot, dolomite, cow manure, phosphoric acid (H$_3$PO$_4$), KCl (60% K$_2$O), Urea (45% N), SP-36 (36% P$_2$O$_5$), insecticide. Profenofos (Curacron 500 EC), Spinosad (Tracer 120 SC), Abamectin (Agrimec 18 EC), Difenoconazole fungusicide (Score 250 EC), Propineb (Antracol 70 WP), Mankozeb (Dithane M-45 80 WP). The tools used were soil test kits for upland (PUTK) to see the status of P and K nutrients in a research location, a roll meter, a hoe, a shovel, a trowel/large knife for taking pieces of soil samples, and other plant cultivation equipment.

Soil analysis was carried out in the soil laboratory of Indonesian Soil Research Institute, Ministry of Agriculture and the laboratory of the Department of Soil and Land Resources, Faculty of Agriculture, IPB University.

2.1. Making of soil P nutrient status
Making nutrient status was started by taking soil samples of research location. Furthermore, the soil sample was analyzed in the soil laboratory to study the maximum P absorption value which was used as the basis for determining the dose of P fertilizer during incubation. The land was cleared and mapped with a size of each plot 1.5 m x 5 m with a height of 0.4 m for incubation.

The single factor treatment design consisted of five levels, from very low, low, medium, high, and very high, with doses of P 0X, 1/4X, 1/2X, 3/4X, and X, respectively, where X was 1033.3 kg P ha$^{-1}$. The X value is half of the maximum P nutrient absorption value.

Absorption of P is the amount of P that must be added to the soil so that the P content in the soil solution reaches 0.2 μg P L$^{-1}$ [2]. Determination of soil P absorption values based on the Fox and Kamprath method [7]. The environmental design used was a randomized block design with five replications.
2.2. Correlation test of P in plastic houses

The correlation test was carried out in a plastic house using a polybag. Single FactorTreatment Design, Environmental Design used Completely Randomized Design, with five replications. As a planting medium, soil samples were taken from ten soil sample points on each plot of soil that had been incubated with P nutrients and soil sampling was carried out randomly. Furthermore, the soil is mixed and composted, then it is dried through air drying. After drying, the soil air is sieved with a size of 2 mm [8]; [6]) then put into polybags as much as 5 kg dry weight. Before planting, dolomite was given at a rate based on the Al-dd value from the results of the initial soil analysis and cow manure at a dose of 2.5ton ha⁻¹ or the equivalent of 11 g of polybag⁻¹. In order to support plant growth, the P correlation test was applied with N fertilizer at a dose of 90 kg N ha⁻¹ or the equivalent of 1 g Urea polybag⁻¹ and K at a dose of 120 kg K₂O ha⁻¹ or the equivalent of 1 g KCl polybag⁻¹, were applied at 10 to 15 and 30 days after planting.

The variables observed were plant height, number of leaves, number of shoots, shoot dry weight, root dry weight, total dry weight, P analysis of plant tissue, and P analysis of soil in each treatment. Soil P analysis was carried out on soil that had been incubated with H₃PO₄ solution, which was taken from each treatment plot. The P extraction methods used in this study were: Bray I (0.025 N HCl + NH₄F 0.03 N solution), Bray II (NH₄F 0.03 N + HCl 0.10 N), Morgan Wolf (NaC₂H₂O₂·3H₂O; pH 4.8), Mehlich I (0.0125 M H₂SO₄ + 0.05 M HCl), and Truog (0.02 N H₂SO₄ + (NH₄)₂SO₄).

Correlation test data were analyzed using analysis of variance to study the effect of soil P nutrient status treatment on plants. If the treatment has a significant effect, then to see the response pattern, it is followed by an orthogonal polynomial test. In the correlation test, regression analysis was also carried out to see the correlation between the P extraction method and the dry weight of the shallot plant. According to [4], the correlation coefficient (r) is determined by the formula:

\[ r = \frac{\Sigma XY}{\sqrt{(\Sigma X^2)(\Sigma Y^2)}} \]

Data analysis used STAR, Minitab 17 and Excel programs.

3. Result and Discussion

3.1. Soil characteristics at the study site

The soil physical and chemical properties of the initial soil in the study site are presented in Table 2. In general, study sites have low to very low soil fertility status. The results of laboratory analysis showed that the soil pH was acid, the soil C-organic and total-N were low, the C/N ratio was moderate, the P content was low, extracted 25% HCl and the available-P was classified as very low, the K content of 25% HCl extract was classified as very low, the exchangeable of K and Na cations were classified as very low, the exchangeable of Ca and Mg cations were classified as low. Cation exchange capacity is low. Based on the results of the analysis of the soil physical and chemical properties, it shows that the soil in the study site was weathered resulting in low availability of primary minerals as a supply of plant nutrients.

Table 1. The soil physical and chemical properties of Ultisol soil od study site

| Characteristics | Measurement Index | Method         |
|-----------------|-------------------|----------------|
| pH H₂O          | 4.57 (acid)       | pH meter       |
| pH KCl          | 3.89 (acid)       | pH meter       |
| Organic matter  |                   |                |
| C-organic (%)   | 1.92 (low)        | Walkley and Black |
| N-organic (%)   | 0.14 (low)        | Kjeldahl       |
| C/N             | 13 (moderate)     |                |
| P Bray I (mg/kg)| 3 (very low)      | Bray-1         |
| P₂O₅ (mg/100 g) | 15 (low)          | HCl 25%        |
| Parameter | Value |
|-----------|-------|
| $K_2O$ (mg/100 g) | 5 (very low) |
| Cation exchange capacity | |
| $K$ (C mol(+)/kg) | 0.06 (very low) |
| $Ca$ (C mol(+)/kg) | 2.66 (low) |
| $Mg$ (C mol(+)/kg) | 0.96 (low) |
| $Na$ (C mol(+)/kg) | 0.09 (very low) |
| $KTK$ | 5.42 (low) |
| $Al$ (C mol(+)/kg) | 3.92 (low) |
| $H$ (C mol(+)/kg) | 0.27 |
| Texture | |
| Sand (%) | 17 |
| Dust (%) | 45 |
| Clay (%) | 38 |

Source: Indonesian Soil Research Institute (2015)

**Figure 1.** The relationship between P fertilization treatment in Ultisol land incubation with the extraction method of P Bray I, P Bray II, P Mechlich I, P Morgan Wolf, and P Truog on P fertilization
3.2. Soil P levels at various soil P nutrient status

Soil P nutrient status can be determined after incubation of P fertilizer using phosphoric acid (H₃PO₄) for three months. The results of soil analysis after incubation using five extraction methods Bray I, Bray II, Mechlich I, Morgan Wolf, and Truog showed an increase in soil P content (Figure 1).

3.3. Plant response to various soil P nutrient status

Soil P nutrient status affected the increase of plant height with a quadratic response pattern at 2 and 4 WAP (Table 2). The increase of plant height was reached at a dose of 774.9 kg P ha⁻¹, then at higher doses it had an effect on decreasing plant height. There is a decrease in plant growth when giving P is very high because excessive fertilizer application will have a negative impact on plant growth due to disruption of root growth/extension [10]. Soil P nutrient status also affected the number of leaves at 2 WAP with a quadratic response pattern, but at 5 WAP the response pattern was linear (Table 3). Meanwhile, for the number of shoots, the correlation test in the greenhouse had a quadratic response pattern at 3, 4, and 5 MST (Table 4). This showed that the role of the addition of P in shallots stimulated an increase in the number of shoots up to a dose of 774.9 kg P ha⁻¹, then a decrease occurs at a very high dose of P. [18] reported that excessive application of P fertilizer will affect the availability of other nutrients which have an impact on of plant growth.

| Soil P Status of applying H₃PO₄ (kg P ha⁻¹) | Plant height (cm, WAP) | Respon pattern |
|-------------------------------------------|------------------------|----------------|
| 0 (0X)                                    | 4.32 19.81 24.84 28.13 28.86 |
| 258.3 (1/4X)                              | 7.15 23.02 27.97 30.77 32.99 |
| 516.6 (1/2X)                              | 7.39 23.18 28.35 31.95 33.36 |
| 774.9 (3/4X)                              | 8.05 22.77 28.34 32.22 33.98 |
| 1033.3 (X)                                | 7.49 21.59 28.31 32.35 33.21 |

| Soil P Status of applying H₃PO₄ (kg P ha⁻¹) | Number of leave (WAP) | Respon pattern |
|-------------------------------------------|------------------------|----------------|
| 0 (0X)                                    | 5.27 9.27 11.33 12.07 13.67 |
| 258.3 (1/4X)                              | 5.93 10.07 12.00 12.93 14.07 |
| 516.6 (1/2X)                              | 6.27 10.53 12.80 13.00 15.07 |
| 774.9 (3/4X)                              | 6.54 10.80 13.54 14.67 16.20 |
| 1033.3 (X)                                | 5.47 9.87 12.86 13.93 15.60 |

| Soil P Status of applying H₃PO₄ (kg P ha⁻¹) | Number of shoots (WAP) | Respon pattern |
|-------------------------------------------|------------------------|----------------|
| 0 (0X)                                    | 2.27 2.93 3.20 3.27 3.40 |
| 258.3 (1/4X)                              | 2.54 3.13 3.53 3.60 3.74 |
| 516.6 (1/2X)                              | 2.60 3.20 3.60 3.67 3.80 |
| 774.9 (3/4X)                              | 2.80 3.27 3.47 3.73 3.87 |
| 1033.3 (X)                                | 2.53 3.00 3.33 3.47 3.80 |

ns= non significant; *= significant; L= Linier; Q= Quadratic; WAP= week after planting
Wet weight of shallot plants has a linear response pattern, plant wet weight has a quadratic response pattern (Table 5). Meanwhile, plant dry weight has a quadratic response pattern (Table 6). The significant effect on wet weight and dry weight of shallots indicated that the P fertilizer incubated for three months showed an increase in P content in the soil which was readily absorbed by plants. Plant dry weight is the variable used in determining the value of the correlation coefficient. The correlation coefficient value was obtained by correlating soil P content and plant dry weight.

Table 5. Wet weight of shallot plants on various soil P nutrient status

| Soil P Status applying of $\text{H}_3\text{PO}_4$ (kg P ha$^{-1}$) | Wet weights (g.plant$^{-1}$) |
|---------------------------------------------------------------|-----------------------------|
|                                                               | Canopy| Root| Plant |
| 0 (0X)                                                        | 5.80  | 0.41| 6.22  |
| 258.3 (1/4X)                                                  | 7.22  | 0.44| 7.67  |
| 516.6 (1/2X)                                                  | 7.71  | 0.50| 8.41  |
| 774.9 (3/4X)                                                  | 8.59  | 0.50| 9.05  |
| 1033.3 (X)                                                    | 8.65  | 0.46| 9.19  |

Respon pattern: L$^*$ ns Q$^*$

ns= non significant; *= significant; L= Linier; Q= Quadratic

Table 6. Dry weight of shallot on various soil P status

| Soil P Status applying of $\text{H}_3\text{PO}_4$ (kg P ha$^{-1}$) | Plant dry weight (g.plant$^{-1}$) |
|------------------------------------------------------------------|-----------------------------------|
|                                                               | Canopy| Root| Plant |
| 0 (0X)                                                          | 0.52  | 0.05| 0.58  |
| 258.3 (1/4X)                                                   | 0.87  | 0.07| 0.94  |
| 516.6 (1/2X)                                                   | 0.94  | 0.08| 1.16  |
| 774.9 (3/4X)                                                   | 1.09  | 0.10| 1.05  |
| 1033.3 (X)                                                     | 0.92  | 0.07| 0.97  |

Respon pattern: ns ns Q$^*$

ns= non significant; *= significant; Q= Quadratic

The addition of soil P through incubation using phosphoric acid for three months significantly increased P levels in the soil. It can be seen that the linear increase in P levels in the shoot (Figure 2). The increase in soil P nutrient content is utilized by plants to a certain dose limit, this can be seen from the response pattern on canopy dry weight which has a quadratic response pattern. According to [16], P given to the soil quickly reacts with other soil materials into forms that are not available to plants, so that plants generally can only absorb P nutrients of no more than 20%. This is in line with the opinion of [17] stated that the continuous use of high P doses of fertilizer resulted in the accumulation of P in the tillage layer due to the low efficiency of P absorption by plants.
Figure 2. The relationship between the addition of soil P with dry weight and crown P

3.4. Correlation of soil P value with uptake and relative yield of plant dry weight

The relationship between the extraction methods of P Bray I, P Bray II, P Mechlich I, P Morgan Wolf, and P Truog and the relative yields of plant dry weight is presented in Figure 3. The study showed that the correlation between soil P nutrient content and the relative yield of plant dry weight, has a correlation coefficient value of the five extraction methods. The best ones are Truog, Morgan Wolf, Mehlich I, Bray I, and Bray II, with each coefficient value. The correlation was 0.77, 0.75, 0.72, 0.72, and 0.70 (Table 7). The correlation between soil P content and plant P nutrient uptake, the best extraction methods are Truog, Mehlich I, Bray II, Bray I, Morgan, with correlation coefficient values of 0.84, 0.81, 0.79, 0.73, 0.67, respectively (Table 8). The difference in the correlation value in each extraction method indicated the level of ability of the extractants to extract available P nutrients for shallot plants in Ultisol soil. The correlation value is 0.70-1.00 (positive or negative), this indicates a high degree of association and a correlation coefficient value of 0.40-0.70 indicates a moderate degree of association [14].
Figure 3. Correlation between extraction methods P Bray I, P Bray II, P Mechlich I, P Morgan Wolf, and P Truog and relative yields of plant dry weight.

Nutrient uptake is multiplication of soil P content (ppm P) with plant dry weight. This study indicated that the correlation between soil P nutrient content and uptake and yield relative to dry weight showed the same results in which the best extraction method is the Truog method. The correlation value between soil P content with the P uptake of the highest was Truog, Bray I, Mechlich I, Bray II, and Morgan Wolf. Plant uptake is presented in Figure 4.
Based on the correlation coefficient of soil P content and relative yields of plant dry weight and plant P uptake, the Truog method is the best method to extract available P nutrients for shallot plants in Ultisol soil (Tables 8 and 9). [11] stated that conducting a soil test must consider selective soil tests, simple, easy to do, easy to obtain chemicals and cheap.

Table 7. The correlation between extracted P and relative yield of plant dry weight at various extraction methods with the

| Method of extraction | Linier equation       | Coefisien correlation (r) |
|----------------------|-----------------------|----------------------------|
| Bray I               | \( Y = 43.119 + 0.2921x \) | 0.70                       |
| Bray II              | \( Y = 42.86 + 0.2178x \)  | 0.72                       |
| Mechlich I           | \( Y = 41.475 + 1.9391x \) | 0.75                       |
| Morgan Wolf          | \( Y = 11.689 + 4.9668x \) | 0.72                       |
| **Truog**            | \( Y = 41.353 + 0.4334x \) | **0.77**                   |

Table 8. The correlation between extracted P and P absorption at various extraction methods

| Method of Extraction | Linier Equation       | Coefisien correlation (r) |
|----------------------|-----------------------|----------------------------|
| Bray I               | \( Y = 1.6638 + 0.0146x \) | 0.73                       |
| Bray II              | \( Y = 1.5979 + 0.0106x \)  | 0.79                       |
| Mechlich I           | \( Y = 1.4553 + 0.1069x \)  | 0.81                       |
| Morgan Wolf          | \( Y = 0.7699 + 0.176x \) | 0.67                       |
| **Truog**            | \( Y = 1.6891 + 0.0248x \) | **0.84**                   |

4. Conclusion

The application of P fertilizer with phosphoric acid (\( H_3PO_4 \)) at various rates increased the soil P status of Ultisol. The correlation between soil P and the relative yield of plant dry weight and plant uptake was significantly different in the extraction methods of Bray I, Bray II, Mechlich I, Morgan Wolf, and Truog. The Truog is the best P extraction method for shallot on Ultisol soil, with a correlation coefficient of 0.77 (for correlation between soil P nutrient content and relative yield of dry weight) and 0.84 (for correlation between plant P nutrient content and plant P uptake). These results can be used to determine recommendations for P fertilization on shallot plants in Ultisol soil.
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