Response of shallots growth and yield to phosphate fertilizer and *Trichoderma* application on peat soil

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Abstract. Cultivating shallots on peat soils is quite challenging since it is considered less fertile regarding its high organic acid content and low nutrient availability. *Trichoderma*, as one of the plant-growth-promoting fungi (PGPF), is beneficial to promote shallots growth. However, there is still lack of information concerning its effectiveness and interaction effect with inorganic P fertilizer in peat soils. This study aimed to investigate the effect of *Trichoderma* application and P fertilization on the growth and yield of shallots on peat soils. A pot experiment arranged in a completely randomized design was conducted with two treatment factors. The first factor was P fertilizer comprised four application rates: 0, 100, 200, and 300 kg ha\(^{-1}\). Meanwhile, as the second factor, *Trichoderma* treatment consisted of four application rates: 0, 2, 4, and 6 g plant\(^{-1}\). The results showed an interaction effect of P treatment and *Trichoderma* on shallots growth and yield. A treatment combination of 2 g plant\(^{-1}\) without P fertilizer addition increased yield by 34% compared to control. This yield was relatively similar to 100 kg ha\(^{-1}\) P fertilizer without *Trichoderma* addition. It is proved that the *Trichoderma* application could reduce inorganic P fertilizer input.

1. Introduction

The cultivation of shallots in Central Kalimantan, especially in Palangka Raya, has been developed on marginal soils since 2013, including in quartzipsamments dan peat soils. Shallots cultivated on peat soils generally had a lower yield compared to quartzipsamment. The highest yield on peat soils and quartzipsamments was 5.8 and 12.4 Mg ha\(^{-1}\), respectively [1]. Palangka Raya peat soil has high cation exchange capacity (CEC) but very low in base saturation and high exchangeable H\(^{+}\) [1]. Nutrient retention, including soil acidity and base saturation, and plant disease were the main constraints of shallots cultivation on peat soil in the rainy season, indicated by the depressed growth and yield [1]. However, plant disease as a constraint was less considerable in the dry season [1]. Peat soils generally have low P availability, and therefore plants often show P deficiency [2]. The peat soils' ability to retain P from P fertilizer is relatively low [3] due to high organic acid concentration that reduces the ability of exchange complex to adsorb negatively charged nutrients such as phosphorus [2]. Furthermore, peat soils are often surrounded by a high humidity environment suitable for fungal disease spreads, hence constraining shallots cultivation [4]. Therefore, proper fertilization and amelioration are required to improve peat soil fertility and shallot productivity [5].

The use of plant growth-promoting fungi (PGPF), particularly *Trichoderma*, has been recognized to be beneficial for plants since its symbiotic association with plant roots could promote crop yield [6]. Furthermore, *Trichoderma* may also serve as a biocontrol agent [7], which beneficial to improve symbiotic plants' disease resistance [8]. Trichoderma's presence may also promote nutrient acquisition,
including phosphorus (P) through the alteration of plant roots architecture or the exudation of substances [9, 10]. *Trichoderma's* multi-benefit as a biofertilizer and biocontrol leads to increased use of these fungi in crop cultivation [11]. It has been reported that the *Trichoderma* application was able to suppress fusarium wilt disease (moler) and increase shallots production [12]. However, there is still lack of information concerning its effectiveness and interaction effect with inorganic P fertilizer in peat soils. The study's objective was to investigate *Trichoderma* and P fertilizer's effect on shallots' growth and yield grown on peat soils.

2. Materials and methods

Materials that used in this study consisted of shallots (Bima Brebes variety), *Trichoderma* biofertilizer, SP36 fertilizer, Urea, KCl, 20x25 cm polybag, peat soils, and mancozeb-based fungicide. The biofertilizer mostly contained *Trichoderma harzianum* and enriched with *Rhizobium* sp, *Azotobacter* sp, *Aspergillus niger*, and *Pseudomonas fluorescens*.

The pot trial was conducted from July to September 2019 in a greenhouse located in Central Kalimantan AIAT complex, Palangka Raya. The factorial experiment was arranged using a completely randomized design with two factors: P fertilizer and *Trichoderma* treatments. The P fertilizer treatments consisted of four levels of SP36 fertilizer rate, as, 0, 0.57, 1.14, and 1.71 g plant⁻¹, equivalent to 0, 100, 200, and 300 kg ha⁻¹. *Trichoderma* treatments comprised four levels of application rate, as 0, 2, 4, and 6 g plant⁻¹. The treatments were replicated three times. The treatments, including P fertilizer and *Trichoderma* biofertilizer, were applied at the same time when planting by spreading them out on the soil surface and subsequently mixed into the soil at the top surface. Two bulbs were planted on each pot, and plants were grown for eight weeks. Plants were harvested at 59 days after planting (DAP) and subsequently weighed and sun-dried. Some plant parameters were recorded during the study. Plant height, leaves number, and tillers number were recorded at 42 DAP while fresh biomass data were collected at harvesting. The last two parameters: dry biomass and dry yield, were recorded the following week after harvesting. All data were analysed using a two-way analysis of variance (ANOVA), and the least significant difference (LSD) test was used to compare the treatments when significant effect existed. All tests were undertaken based on a 5% significance level.

3. Results and discussion

The statistical analysis results showed that the interaction effect existed between P fertilizer and *Trichoderma* treatment on most plant parameters, including plant height, leaves number, fresh and dry biomass, and dry yield, except tillers number. However, *Trichoderma* treatment had a positive effect on the tillers number, but there was no significant P fertilizer treatment effect.

A *Trichoderma* application rate of 2 g plant⁻¹ and 200 kg ha⁻¹ P fertilizer resulted in increased plant height by 65% compared to control (no P fertilizer and *Trichoderma* addition) (table 1). Furthermore, the highest number of leaves by 43.67, was achieved by the treatment combination of 4 g plant⁻¹ *Trichoderma* and 100 kg ha⁻¹ P fertilizer rate (table 3). *Trichoderma's* single factor, particularly 4 g plant⁻¹, significantly increased tillers number by 112% compared to control, and it was also significantly different with 2 g plant⁻¹ *Trichoderma* (table 2). Increased tiller number presumably was attributable to increased N uptake from the soil that previously had been added with N fertilizer (urea) due to *Trichoderma's* presence [13].

Shallots plant growth showed a positive response to *Trichoderma* and P fertilizer application. *Trichoderma's* positive effect is closely related to its ability to improve soil fertility and nutrients availability. As a biofertilizer, *Trichoderma* plays an essential role in plant growth and development by the colonization of plant roots to improve nutrient uptake. *Trichoderma* is able to maintain soil fertility, increase indigenous microbial activity, break down organic matters and soil minerals, and release plant-available nutrients [14]. Furthermore, increasing the *Trichoderma* application rate was in line with the increasing growth and yield of tomatoes [15].

Phosphate fertilizer's positive effect had been found presumably because P application would likely increase P availability for plants. Phosphorus is critical to cell nucleus formation, cell division, cell
multiplication, roots growth, and roots development [16]. *Trichoderma* may also influence the availability of P. Apart from being a biocontrol agent, the fungus also plays a vital role in organic matter decomposition in soils releasing humic acid and fulvic acid, which beneficial to increase P availability [17]. Humic and fulvic acid are essential in releasing P from bounded P and, therefore, being available for plant roots [18, 19]. Moreover, *Trichoderma* and plant roots' symbiotic relationship enhances nutrient acquisition, especially P [20, 21].

**Table 1.** Interaction effect of P fertilizer and *Trichoderma* on plant height of shallots (n=3)a.

| SP36 (kg ha⁻¹) | Trichoderma (g plant⁻¹) | 0   | 2   | 4   | 6   |
|----------------|--------------------------|-----|-----|-----|-----|
| 0              |                          | a   |      | b   |      |
| A              |                          | A   |      | A   |      |
| 100            |                          | a   |      | a   |     |
| B              |                          | B   |      | A   |     |
| 200            |                          | a   |      | b   |     |
| A              |                          | B   |      | A   |     |
| 300            |                          | a   |      | b   |     |
| A              |                          | AB  |      | A   |     |

CV (%) = 14.98

*aLowercase refers to the difference between *Trichoderma* treatments on the same SP36 treatment, while the uppercase refers to the difference between SP36 treatments on the same *Trichoderma* treatment. Means followed by the same letters are not significantly different at the 0.05 significance level of the LSD test.

**Table 2.** Effect of *Trichoderma* and P fertilizer treatment on tillers number of shallots.

| Trichoderma (g plant⁻¹) | Tillers number |
|--------------------------|----------------|
| 0                        | 14.00 a        |
| 2                        | 17.00 a        |
| 4                        | 29.67 b        |
| 6                        | 32.58 b        |
| LSD 5%                   | 4.63           |

**SP36 (kg ha⁻¹)**

| 0              | 23.83          |
| 100            | 23.00          |
| 200            | 22.33          |
| 300            | 24.08          |
| ns             |                |

*aNumerical values are arithmetic means (n=12). bMeans followed by the same lowercase letters indicate non-significant differences at 0.05 significance level of LSD test.
Table 3. Interaction effect of P fertilizer and *Trichoderma* on leaves number of shallots (n=3)*a*.

| SP36 (kg ha⁻¹) | Trichoderma (g plant⁻¹) | 0    | 2     | 4     | 6     |
|----------------|-------------------------|------|-------|-------|-------|
|                |                         | A    | AB    | A     | A     |
| 0              | 11.33                   | a    | 28.67 | c     | 22.33 | bc    | 15.33 | ab    |
| 100            | 12.33                   | a    | 30.67 | b     | 43.67 | c     | 13.67 | a     |
| 200            | 12.67                   | a    | 35.33 | b     | 39.67 | b     | 13.00 | a     |
| 300            | 15.00                   | a    | 24.67 | b     | 43.67 | c     | 12.33 | a     |
| CV (%)         |                         |      |       |       |       |       | 24.85 |

Lowercase refers to the difference between *Trichoderma* treatments on the same SP36 treatment, while the uppercase refers to the difference between SP36 treatments on the same *Trichoderma* treatment. Means followed by the same letters are not significantly different at the 0.05 significance level of the LSD test.

The combination treatment of 4 g plant⁻¹ *Trichoderma* and 300 kg ha⁻¹ P fertilizer resulted in the highest fresh biomass by 84.13 g. Meanwhile, the highest dry biomass by 58.9 g was achieved by a treatment combination of 300 kg ha⁻¹ P fertilizer without *Trichoderma* addition, but it was not significantly different with 100 kg ha⁻¹ P fertilizer. Though P fertilizer's addition improved dry biomass, increasing the P fertilizer rate had no benefit to plants. Possibly, there was a P loss due to the low ability of peat soil to retain readily soluble P from inorganic P fertilizer [3]. The P availability was quickly increased following the P fertilizer application, and the plant showed a positive response. However, plants may not get significant benefits from increasing the P fertilizer rate since most soluble P did not remain longer because the soil could not retain the nutrients from leaching [2].

Table 4. Interaction effect of P fertilizer and *Trichoderma* on fresh weight of shallots (n=3)*a*.

| SP36 (kg ha⁻¹) | Trichoderma (g plant⁻¹) | 0     | 2     | 4     | 6     |
|----------------|-------------------------|-------|-------|-------|-------|
|                |                         | A     | AB    | A     | A     |
| 0              | 52.07                   | a     | 74.57 | b     | 73.30 | b     | 64.80 | ab    |
| 100            | 76.57                   | a     | 67.97 | a     | 59.23 | a     | 71.13 | a     |
| 200            | 77.37                   | a     | 85.33 | a     | 73.80 | a     | 75.90 | a     |
| 300            | 71.33                   | ab    | 61.43 | a     | 84.13 | b     | 75.77 | ab    |
| CV (%)         |                         |       |       |       |       |       | 15.21 |

*Lowercase refers to the difference between *Trichoderma* treatments on the same SP36 treatment, while the uppercase refers to the difference between SP36 treatments on the same *Trichoderma* treatment. Means followed by the same letters are not significantly different at the 0.05 significance level of the LSD test.*
Table 5. Interaction effect of P fertilizer and *Trichoderma* on the dry weight of shallots (n=3)

| SP36 (kg ha\(^{-1}\)) | Trichoderma (g plant\(^{-1}\)) | 0  | 2  | 4  | 6  |
|------------------------|---------------------------------|----|----|----|----|
| 0                      |                                 | 43.43 | a | 51.77 | a | 45.67 | a | 40.83 | a |
|                        |                                 | A   | B  | AB  | A  |
| 100                    |                                 | 56.50 | b | 53.40 | b | 43.33 | a | 52.73 | ab |
|                        |                                 | B   | B  | A   | A  |
| 200                    |                                 | 53.20 | a | 51.57 | a | 48.43 | a | 51.60 | a |
|                        |                                 | AB  | B  | AB  | A  |
| 300                    |                                 | 58.90 | b | 38.67 | a | 57.10 | b | 51.27 | ab |
|                        |                                 | B   | A  | B   | A  |

CV (%) = 15.66

\(^a\)Lowercase refers to the difference between *Trichoderma* treatments on the same SP36 treatment, while the uppercase refers to the difference between SP36 treatments on the same *Trichoderma* treatment. Means followed by the same letters are not significantly different at the 0.05 significance level of the LSD test.

A combination treatment of 2 g plant\(^{-1}\) *Trichoderma* without P fertilizer addition resulted in the optimum yield by 50.10 g dry bulb or 34% higher than the control. Improving yield was most likely caused by increased nutrient availability due to *Trichoderma*’s organic matter decomposition, promoting plant photosynthesis. A previous study showed that the combination of 15 Mg ha\(^{-1}\) Trichokompos TKKS and 120 kg P\(_2\)O\(_5\) ha\(^{-1}\) P fertilizer produced the highest fresh bulbs by 7.65 g [16]. Increased photosynthesis would enhance photosynthate’s translocation into bulbs and increase yield [22].

Table 6. Interaction effect of P fertilizer and *Trichoderma* on the yield of shallots (n=3)

| SP36 (kg ha\(^{-1}\)) | Trichoderma (g plant\(^{-1}\)) | 0  | 2  | 4  | 6  |
|------------------------|---------------------------------|----|----|----|----|
| 0                      |                                 | 37.37 | a | 50.10 | b | 43.57 | ab | 39.27 | ab |
|                        |                                 | A   | B  | A   | A  |
| 100                    |                                 | 50.33 | a | 51.53 | a | 40.77 | a | 44.90 | a |
|                        |                                 | B   | B  | A   | A  |
| 200                    |                                 | 52.03 | a | 49.70 | a | 46.63 | a | 50.10 | a |
|                        |                                 | B   | B  | AB  | A  |
| 300                    |                                 | 51.20 | b | 37.03 | a | 56.73 | b | 49.53 | b |
|                        |                                 | B   | A  | B   | A  |

CV (%) = 15.51

\(^a\)Lowercase refers to the difference between *Trichoderma* treatments on the same SP36 treatment, while the uppercase refers to the difference between SP36 treatments on the same *Trichoderma* treatment. Means followed by the same letters are not significantly different at the 0.05 significance level of the LSD test.
The higher rate of either *Trichoderma* or P application did not significantly result in a higher yield than the previous treatment combination. Furthermore, 2 g plant\(^{-1}\) *Trichoderma* without P fertilizer resulted in a similar yield to 100 kg ha\(^{-1}\) P fertilizer without *Trichoderma* application suggesting that the *Trichoderma* application may reduce the need for inorganic P fertilizer. In terms of improving P efficiency, *Trichoderma* may have a positive role; however, *Trichoderma*'s effect was less prominent in the presence of P fertilizer. To some extent, inorganic P fertilizer application on plants inoculated with *Trichoderma* may not increase yield [23]. Furthermore, our findings also confirm the necessity of implementing the *Trichoderma* and inorganic P fertilizer at a reasonable rate.

### 4. Conclusions

The treatment combination of 2 g plant\(^{-1}\) *Trichoderma* without P fertilizer addition produced an optimum yield of 50.10 g plant\(^{-1}\) or 34% higher than the control. This yield was relatively similar to the application of 100 kg ha\(^{-1}\) P fertilizer without *Trichoderma* addition. This present result confirmed that the *Trichoderma* application could reduce P fertilizer input on shallots grown on peat soils.

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