Application of lake sludge and natural phosphate on spinach plant cultivation (*Amaranthus tricolor* L.)

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Abstract. Lake sludge and natural phosphate can be applied to the cultivation of various plants, but have not been applied to spinach cultivation. The aim of the study was to determine the effect of Lake Sludge dosage and Natural Phosphate dosage on growth and yield of unripe spinach. The experimental method with factorial RCBD used in this research. The results showed that the interaction between the treatment of lake sludge doses and natural phosphate doses did not significantly influence all observed variables. The highest yield for total dry weight per plant was obtained from the treatment of 150 g/polybag lake sludge which was 8.07g, and in the treatment of 40 g/polybag of natural phosphate dose which was 7.31 g. Both of the regression analysis between the dosages of Lake Sludge and Natural Phosphate with total oven dry weight per plant there is a linear relationship.

1. Introduction

Spinach (*Amaranthus tricolor* L.) is a group of vegetables that contain lots of vitamin A, vitamin C, and minerals, especially iron [1-3]. One effort that needs to be done to improve the yield and quality of spinach is by fertilizing using sludge as organic fertilizer. The good influence of the use of this sludge is to increase the ability of materials to bind soil moisture and soil structure [2]. The chemical composition of the river and swamp sludge deposits are as follows: BO 3.2%, N-total 0.23%, P$_2$O$_5$ 0.46 ppm, K$_2$O 0.38 ppm [4-6].

The main components for making compost fertilizer in China are 7.6 tons of river mud, 0.15 tons of rice straw, 0.02 tons of superphosphate, 1.0 tons of pig manure and 0.75 tons of water plants. The use of lake sludge in principle improves the quality of soil enhancers and increases the growth and yield of plants developed using this sludge as a planting medium [6-8]. That is acid soils that require P, the use of natural phosphate is considered more effective and cheaper than other P forms because natural phosphate is more reactive and more economical.

In general, natural phosphate deposits in Indonesia have P$_2$O$_5$ levels that vary greatly from low to moderate and there are several deposits that reach P$_2$O$_5$ levels up to 40%. Levels of natural P$_2$O$_5$ phosphate are higher than chicken manure which ranges from 2.80 % - 6.00%. Natural phosphate reactivity or natural phosphate solubility for plants also varied greatly (<1 - 18% P$_2$O$_5$) [9,10]. Natural phosphate has a long-term residual effect because it has slow release properties, therefore natural phosphate can be given at the same time when planting and can be used for the next several seasons [11]. In connection with this description, the treatment of Lake Sludge and Natural Phosphate is tried to increase the growth and yield of spinach. The aim of the study was to determine the effect of Lake.
Sludge and Natural Phosphate doses on growth and yield of spinach.

2. Materials and methods
This experiment was conducted at the Experiment Station of the Faculty of Agriculture, Warmadewa University, Denpasar, Bali, Indonesia. The factorial experiment was a randomized block design consisting of 2 factors with Lake Sludge 4 dose level, i.e. 0 g per polybag (10 kg soil media), 50 g per polybag, 100 g per poly bag and 150 g per polybag, while the dosage of Natural Phosphate (F) with 3 levels were 0 g per polybag, 20 g per polybag and 40 g per polybag. Thus in this experiment, there were 12 combination experiments which were repeated 3 times so that 36 polybags were needed.

3. Results and discussion
The results of statistical analysis show that the significance of the treatment of lake sludge (D) doses and natural phosphorus doses (F) and their interactions (D x F) for all observed variables are presented in Table 1. Interactions between lake sludge sediment doses (D) and doses natural phosphorus (F) (D x F) has no significant effect on all observed variables. The lake mud dose (D) had a very significant effect on all observed variables, while the Phosphate Natural fertilizer dose (F) had a significant effect on all observed variables.

Table 1. Significance of the effect of Lake Mud Deposits (D) and natural phosphate (F) and their interactions (D x F) on all observed variables.

| No. | Variables                        | Treatment |
|-----|----------------------------------|-----------|
| 1.  | Maximum plant height (cm)        | **        |
| 2.  | Maximum number of leaves (strands) | **      |
| 3.  | Leaf area (cm²)                  | **        |
| 4.  | Total plant fresh weight (g)     | **        |
| 5.  | Economical fresh weight per plant (g) | **   |
| 6.  | Total oven dry weight of plant (g) | **     |
| 7.  | Economical oven dry weight per plant (g) | **   |

Description: ns (no significant), * (significant), ** (very significant)

3.1. The height of the spinach plant
The results of the statistical analysis showed that the dose of Lake Sludge (D) and Natural Phosphate (F) and the interaction between Lake Sludge (D) and Natural Phosphate fertilizer dose (F) had no significant effect on maximum plant height (Table 2).

3.2. Number of leaves
The results of statistical analysis show that Lake Sludge (D) does have a very significant effect on the maximum number of leaves per plant and Natural Phosphate fertilizer dose (F) and their interactions (D x F) have no significant effect on these variables (Table 2). At a dose of 50 g per polybag, the maximum number of leaves yields 9.44 leaves which are significantly different from doses of 0 g and 150 g. In the treatment of dosages of Natural Phosphate fertilizer of 40 g per polybag which produced the highest number of leaves 10.16 leaves are different when compared with doses of 0 g per polybag and 20 g per polybag, each of which produces 8.66 strands of leaves and 9.33 strands

3.3. Leaf area (cm²)
The results of statistical analysis show that Lake Sludge (D) and Natural Phosphate (F) does have a very significant effect on leaf area while the interaction between lake sludge sediment with Natural Phosphate (D x F) has no significant effect (Table 1). The highest treatment of Lake Sludge fertilizer dosage was obtained in D3 treatment of 210.74 cm². In the phosphate dosage treatment, it turned out that the average
yield of the largest leaf area was obtained in the F2 treatment of 184.39 cm² which was significantly different when compared with the treatments of F1 and F0.

Table 2. The effect of lake sludge and natural phosphate on average maximum plant height, maximum leaves, and leaf area.

| Treatment          | Maximum plant height (cm) | Maximum number of leaves (strands) | Leaf area (cm²) |
|--------------------|----------------------------|------------------------------------|-----------------|
| Lake Sludge (D)    |                            |                                    |                 |
| 0 g/polybag (D0)   | 20.61 c                    | 7.88 c                             | 132.84 c        |
| 50 g/polybag (D1)  | 20.87 b                    | 9.44 b                             | 147.96 c        |
| 100 g/polybag (D2) | 22.76 b                    | 9.22 b                             | 171.89 b        |
| 150 g/polybag (D3) | 27.60 a                    | 11.00 a                            | 210.24 a        |
| BNT 5%             | 2.02                       | 0.82                               | 20.69           |
| Natural Phosphate  |                            |                                    |                 |
| 0 g/polybag (F0)   | 22.40 b                    | 8.66 b                             | 146.37 c        |
| 20 g/polybag (F1)  | 23.00 b                    | 9.33 b                             | 166.44 b        |
| 40 g/polybag (F2)  | 24.98 a                    | 10.16 ab                           | 184.39 a        |
| BNT 5%             | 1.75                       | 0.71                               | 17.92           |

Description: The numbers followed by the same letter notation in the same treatment and column means that there is no significant difference in the 5% BNT test

3.4. Total fresh weight per plant (g)

The results of statistical analysis showed that both the lake sludge deposition fertilizer (D) and the natural phosphate sausage (F) had a very significant effect but the interaction between the lake sludge sediment dose and Natural Phosphate (D x F) had no significant effect on the total wet weight of the plant (Table 3). The average total wet weight per plant in the highest treatment of lake sludge (D) was obtained in the D3 treatment of 80.33g which was significantly different from the other treatments. While the D2 treatment was different than the D1 and D0 treatment as well as the D1 treatment was higher than the D0 treatment. The highest phosphate treatment (F) results were obtained in the F2 treatment of 61.85g which was significantly different from the F1 treatment of 54.31 g and was significantly different compared to the F0 treatment of 45.98g.

3.5. Economical fresh weight per plant (g)

The results of statistical analysis showed that the dose of lake sludge (D) and natural phosphate (f) fertilizer had a very significant effect on the interaction between lake sludge sediment and natural phosphate which had no significant effect on economic weight (Table 3). The average economic wet weight of the plants in the treatment of lake sludge (D) was highest obtained in the D3 treatment of 69.47 g which was significantly different from the other treatments. While the treatment of D2 was significantly higher than the treatment D1 and D0, as well as the treatment of D1 was significantly higher when compared to treatment D0. The highest results of phosphate treatment (F) was obtained in the F2 treatment of 54.27 g which was very real significantly compared to F0 of 40.51 g.

3.6. Weight of dry oven total plant (g)

The results of the statistical analysis showed that the lake sludge dose (D), natural phosphate dosage (F) had a very significant effect on total oven dry weight but the interaction between lake sludge sediment and natural phosphate had no significant effect on dry weight total oven plants (Table 3). The average total oven dry weight per plant in the highest treatment of lake sludge (D) was obtained in D3 treatment of 8.07 g which was significantly different from D2 treatment of 6.13 g and significantly different from treatments D1 and D0 each of 5.83 g and 5.01 g. Whereas in the highest phosphate treatment (F) the highest results were obtained in the F2 treatment of 7.31 g which was different from the F1 treatment of 6.23 g and significantly different compared to F0 of 5.24 g. The F2 treatment was significantly higher.
when compared to treatment F0.

**Table 3.** The Effect of Lake Sludge and Natural Phosphate on Total plant fresh weight and Economical fresh weight per plant.

| Treatment | Total plant fresh weight (g) | Economical fresh weight per plant (g) | Total oven dry weight of plant (g) | Economical oven dry weight per plant (g) |
|-----------|-----------------------------|--------------------------------------|-----------------------------------|----------------------------------------|
| Lake Sludge (D) |                               |                                      |                                   |                                        |
| 0 g / polybag (D0) | 32.54 d                      | 29.76 d                             | 5.01 e                            | 4.21 c                                 |
| 50 g / polybag (D1) | 44.63 c                      | 38.50 c                             | 5.83 bc                           | 4.90 bc                                |
| 100 g / polybag (D2) | 58.68 b                      | 50.83 b                             | 6.13 b                            | 5.16 b                                 |
| 150 g / polybag (D3) | 80.33 a                      | 69.47 a                             | 8.07 a                            | 6.76 a                                 |
| BNT 5 % | 6.46                         | 6.40                                | 0.97                               | 0.82                                    |
| Natural Phosphate |                               |                                      |                                   |                                        |
| 0 g / polybag (F0) | 45.98 c                      | 40.51 c                             | 5.24 c                            | 4.40 c                                 |
| 20 g / polybag (F1) | 54.31 b                      | 46.64 b                             | 6.24 b                            | 5.22 b                                 |
| 40 g / polybag (F2) | 61.85 a                      | 54.27 a                             | 7.31 a                            | 6.15 a                                 |
| BNT 5 % | 5.60                         | 5.54                                | 0.84                               | 0.72                                    |

Description: The numbers followed by the same letter notation in the same treatment and column means that there is no significant difference in the 5% BNT test.

### 3.7 Economical dry oven weight per plant (g)

The results of statistical analysis showed that the treatment of lake sludge (D), and Natural Phosphate dosage (F) had a very significant effect on the oven dry weight per plant for interactions between lake sludge deposits and Natural Phosphate (D x F) which differed significantly from the weight dry oven economical per plant (Table 3).

The average economical oven dry weight per plant in the highest treatment of lake sludge (D) deposits was obtained in D3 treatment of 6.76 g which was significantly different from treatments D2, D1, and D0. Whereas in the highest phosphate treatment (F) the highest yield was obtained by treatment F2 of 6.15 g which was significantly different from the treatments of F1 and F2 of 5.22 g and 4.40 g. While the F1 treatment was different not significantly with treatment F0 where F1 treatment was greater. The total oven dry weight per plant in the treatment dose of 150 g per polybag was due to an increase in plant nutrition and improvement in the physical, chemical and biological properties of the soil, using sludge deposition fertilizers where the sludge contained a total N-element of 0.34%, P-available 50.15 ppm and K-available 377.68 ppm and other ingredients, thus the need for plants to grow and develop for the better. This is in accordance with [2, 6] statement that in broad outline the benefits obtained by utilizing lake sludge as organic fertilizer are improving soil physical properties, improving soil chemical properties and influencing soil biological properties. Furthermore, it was stated that the use of lake mud would increase the ability of materials to bind soil moisture and improve soil structure. By improving the physical properties of the soil and increasing the nutritional status of the soil, the soil will become loose, the growth of underground plants will be better, thus supporting the growth of the soil for the better. This is indicated by increasing growth variables, such as increasing the maximum number of leaves, and leaf area, this will encourage faster plants to grow and develop. Natural phosphate treatment has a very significant effect on the total oven dry weight variable per plant. Natural phosphate dosage 40 g per polybag (F2) gives total oven dry weight per plant of 7.31 g or 14.73% and 28.31% higher than a dose of 20 g per polybag (F1) and without natural phosphate (F0) each of which was 6.23 g and 5.24 g (Table 3). The results of the regression analysis between natural phosphate doses with total oven dry weight per plant there is a linear relationship with the equation Ŷ = 5.2299X + 0.0518 with R2 = 99.94% (Figure 2). The total oven dry weight per plant of Natural Phosphate treatment at a dose of 40 g per polybag was 28.34% higher than without Natural Phosphate. The increase in these variables is supported by increasing economical oven dry weight per plant. Natural phosphate doses give economical oven dry weights higher than without Natural Phosphate.
weight per plant at a dose of 40 g per polybag at 6.15 g or increase by 28.34% compared to no natural phosphate. Increased total oven dry weight per plant in the treatment due to increased leaf area, which due to increased leaf area to a certain extent will increase the efficiency of light interception per unit area and increase photosynthetic activity, then followed by the accumulation of larger dry matter.

The increase in the yield of unplugged spinach cannot be separated from the role and function of natural phosphate which can increase soil fertility through absorption of some nutrients [6,11], that natural phosphate contains Ca-phosphate (Ca, Al, Fe) phosphate or (Al, Fe) phosphate so that it will improve the physical and chemical properties of the soil. Furthermore that the benefits that can be obtained using Natural Phosphate directly in addition to lower prices than artificial phosphate, Natural Phosphate has other elements, namely Ca, Al and Fe which are relatively high compared to artificial fertilizers, so natural phosphate fertilizer can be used to improve the physical and chemical properties of the soil. With the P content in Natural Phosphate, the nutritional elements to meet the needs of plants will be fulfilled, so plant growth will be good [9,11]. Increased nutritional status of plants, mainly due to the administration of P elements (phosphate), which can improve the growth of underground plants (especially root growth and development), because of one function P (phosphate) is to stimulate root growth in young plants. With good root growth and development, it will support the growth of plants on the ground for the better, as evidenced by the increase in economical wet weight and economical oven dry weight of the crop in the treatment [6,10].
4. Conclusions
The interaction between the treatment of lake sludge doses and natural phosphate doses did not significantly influence all observed variables. The highest yield for total dry weight per plant was obtained from the treatment of 150 g/polybag lake sludge which was 8.07g, and in the treatment of 40 g/polybag of natural phosphate dose which was 7.31 g. The results of regression analysis between doses of lake sludge with total dry weight per plant have a linear relationship with the regression equation Ŷ = 4.8455X + 0.0189 with R² = 89.20% as well as regression analysis between natural phosphate doses with total dry weight per plant linear relationship with the equation Ŷ = 5.2299X + 0.0158 with R² = 99.94%.

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