Growth and P absorption of *Fibraurea tinctoria* lour in peat soil with an amendment

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Abstract. One of the ways to maintain and increase immunity during the COVID-19 pandemic is by consuming the medicinal plant. Indonesia has many medicinal plants, one of which is ‘akar kuning’ (*Fibraurea tinctoria* Lour). *F. tinctoria* is a wild plant commonly found in Kalimantan and has not been widely cultivated. Therefore, efforts to develop need to be made, especially in peat soil. An approach to addressing the problem in peat soils is adding zeolite amendments and NPK fertilizer to increase growth. Therefore, preliminary research was conducted to determine the growth and P absorption of *F. tinctoria* in peat soil. The study used Zeolite (0 and 2.5 g polybag⁻¹) and NPK fertilizer with three levels (3, 6, 9 g plant⁻¹). The combination treatments were arranged factorially on a completely randomized design. The study shows different responses to the leaf number, root volume, and root dry weight. Tendril length and P absorption increased along with the increase of Zeolite and NPK application.

1. Introduction

Maintaining and enhancing immunity during the COVID-19 pandemic needs to be done to avoid the risk of this disease. One way that can be taken is by consuming herbs that can increase immunity. Indonesia is rich in various plant species that are beneficial for health and often used as a choice of traditional medicine to treat numerous diseases. ‘Akar kuning’ (Yellow root) is one of them. ‘Akar kuning’ contains alkaloids and can also be used as antiseptics [1]. Besides being an immunity enhancer, ‘akar kuning’ also contains berberine chloride, 8-hydroxy berberine, jatrorrhizine, limasina, and palmatine [2]. Some researchers have proved the medicinal efficacy of ‘akar kuning’ plants as antimarial, cure cervical cancer and prostate cancer, as a hepatoprotection, anti-bacterial, and so on [2–4].

‘Akar kuning’ is a liana (climbing plant) that belongs to the Family Menispermaceae, including *Coscinimum fenestratum* (Gaertn.) Colebr., *Fibraurea tinctoria* Lour and *Arcangelisia flava* (L.) Mer [4]. In the IUCN red list, the ‘akar kuning’ both *C. fenestratum* and *F. tinctoria* have been declared rare because of the continuous and direct retrieval by the community from its natural habitat. In contrast, slow natural propagation and cultivation efforts do not exist yet [5,6], so conservation efforts are necessary. One alternative in the cultivation of *F. tinctoria* is the use of marginal lands, such as peat soils.
Peat soil utilization for agriculture faces problems physically, chemically, and biologically because the characteristics of peat soil are very different from mineral soils. Physical constraints such as excess water, high acidity, low availability of macro and micronutrients, and organic acids are toxic to plants. Peat soils chemically have a high soil acidity due to organic acids and the decomposition of organic matter in anaerobic conditions [7]. Peat soils have a high cation exchange capacity (CEC) but very low alkaline saturation, so the availability of nutrients, especially macronutrients (K, Ca, Mg, P) and micro (Cu, Zn, Mn, and Bo) are low. The availability of P in peat soil is low. Phosphorus in peat soils are primarily found in organic P forms, especially inositol phosphate, which are very slow-release, thus less available for plants [8–10].

An alternative effort to improve peat soil conditions is to add amendments and balanced fertilization of site-specific soil testing and crop needs. Zeolite as an amendment can be used with minerals or organic fertilizers to increase plant growth. The addition of Zeolite into the soil is intended for stabilizing soil materials that can raise pH, CEC, water holding capacity, and nutrients and serve as slow-release fertilizer [11–13]. Zeolite can also maintain soil moisture, soil structure and regulate soil nutrition [11,14,15]. Some research suggested that Zeolite as an amendment might act as a macro nutritional supplement. Zeolites can retain nutrients in the soil and are slowly and gradually released [14] Zeolite application in sugar cane can increase yields, and Zeolite combined with organic fertilizer shows better growth [15]. Zeolite applied together with organic fertilizer, or NPK (15:15:15) lowers acidity, increases humus content, total N, and increases the availability of P and K [16]. As a first step in cultivating F. tinctoria in peat soil, research was conducted to obtain Zeolite dosage that needs to be added to F. tinctoria and study P absorption.

2. Methodology

The research was conducted in February–November 2019 at Wedomartani Ngemplak Sleman, Indonesia. The study consists of two treatments, namely Zeolite with two levels (0 and 2.5 g polybag⁻¹) and NPK fertilization (16:16:16) with three levels 3, 6, 9 (g plant⁻¹). Each combination of treatments was repeated three times. The treatment combinations were factorially arranged based on a complete randomized design.

Research began by sowing F tinctoria seed and preparation of planting media. The peat soil from ‘Rawa Pening’ was used as growing media dredged and filtered with a sift of Ø 2 mm, and Ø 0.5 mm. The planting media was peat and manure with a ratio of 3:1 as much as 5 kg polybag⁻¹ and had been given Zeolite incubated for three weeks. Fertilization was applied when transplanting. Plant maintenance was carried out one week two times, including watering, weeding, pest control, and disease using natural pesticides. Measurements and observations include the characteristics of peat soil, plant growth such as tendril length, number of leaves, root volume, dry weight of roots, and P absorption. Soil characteristic data were presented descriptively, growth and P absorption were analyzed with ANOVA and Duncan test using Minitab data processor.

3. Results and discussion

3.1. Characteristics peat soil

The initial soil analysis is shown in Table 1. The texture of peat soil was clay, with 13% sand, 7% silt, and 80% clay. The texture is very influential to tillage, water holding capacity, and plant roots development [17]. The analysis of the chemical properties of pH in Table 1 shows that the peat soil used has a pH H₂O of 5.07 and is included in the acid criteria. The acidity of peat soil is caused by the accumulation of organic material leftover weathering and soil in anaerobic environmental conditions so that organic acids such as phenolic compounds and carboxylic are formed. pH is a parameter controlled by the colloidal electronic properties of soil colloids [18]. The level of acidity affects the availability of nutrients in the soil because nutrients are widely available at a range of pH 6.0–6.5.

N-total content of the initial soil in the peat showed a very high of 1.60%, and the C/N ratio was 11.36 (medium). The high N is due to the origin of N-organic soil or previously available due to the
mineralization process. The high C/N ratio value in peat soils can cause complex decomposition, but if C/N is low, it will be easy and quickly decomposed [19]. The perfect decomposition process causes the availability of nutrients to be high. The available P and K on peat soils are low, namely 6.01 ppm and 13.29 mg 100 g⁻¹, respectively. Organic matter accumulation in peat soil has not been decomposed perfectly, causing low availability of P and K. This is also reported by some researchers, which states the low P content in peat, which is about 0.05–0.2% of dry land [8–10]. The availability of P in peat soil is strongly influenced by soil pH, Fe, Al ions, and organic matter decomposition levels [20].

**Table 1. Characteristics of peat soil ‘Rawa Pening’**

| No. | Soil properties | Value | Unit   | Classify  |
|-----|-----------------|-------|--------|-----------|
| 1   | pH H₂O          | 5.07  |         | Acid      |
| 2   | Texture (sand)  | 13    | %      | Clay      |
|     | (clay)          | 7     | %      |           |
| 3   | Total N         | 1.60  | %      | Very high |
| 4   | Available P     | 6.01  | ppm    | Low       |
| 5   | Available K     | 13.29 | mg100 g⁻¹ | Low     |
| 6   | Available C/N   | 18.18 | %      | Very high |
| 7   | C/N Ratio       | 11.36 |        | Medium    |
| 8   | CEC             | 85.94 | m.e.100 g⁻¹ | Very high |

Source: Laboratory analysis from Soil Chemistry and Fertility Agriculture Faculty UNS
*According to Eviati and Sulaeman [21].

3.2. Peat soil analysis after incubation

Chemical analysis of peat soils incubated with Zeolite for three weeks showed an increase in soil pH. Zeolite increases the pH from 5.07 to 6.70. The increased pH is caused by the saturation of Al and Fe, which begins to decrease. Zeolite can absorb Al and Fe into negatively charged cavities so that the saturation of Al and Fe in the soil solution becomes reduced and increases the pH [22–24].

The addition of Zeolite to peat soil increases CEC from 85.94 m.e.100 g⁻¹ to 86.63 m.e.100 g⁻¹. CEC is directly proportional to the pH; CEC will decrease when the peat pH drops and vice versa [23]. Munthali [24] explains that zeolite cation exchange is a function of the substitution degree of silica by aluminium in the crystalline structure of Zeolite. The more aluminium replaces the silica position, the more negative charge is produced, so the higher CEC. There was an increase of 30–40% CEC in natural zeolite applications and 40–50% in synthetic zeolite applications [25]. Increasing CEC is due to the high ability to adsorb cations that are not tightly bound in the zeolite crystal framework, increasing plant nutrient uptake [9].

**Table 2. pH and CEC planting media after incubation for three weeks**

| No. | Soil properties | Value | Unit       | Classify |
|-----|-----------------|-------|------------|----------|
| 1   | pH H₂O          | 6.7   | -          | Neutral  |
| 2   | CEC             | 86.63 | m.e.100 g⁻¹ | Very high |

Source: Laboratory analysis from Soil chemistry and fertility Agriculture Faculty Sebelas Maret University.
* according to Eviati and Sulaeman [21].

3.3. Plant growth

Analysis of variance shows an interaction between Zeolite and NPK fertilization to the number of leaves, root volume, and root dry weight. Zeolite has a significant impact on the length tendrils and P absorption (Table 1). Increasing pH from 5.5 (acid) to 6.7 in peat soils with amendments improves nutrient absorption activity.
The response of leaves number, the roots volume, and the roots dry weight of F tinctoria shows the difference with Zeolite and NPK fertilizers (Table 3, Table 4). The application of Zeolite together with NPK fertilization increases those parameters. However, the increase in NPK dosage does not significantly increase such parameters. In media without Zeolite, increasing fertilizer dosage does not considerably increase the number of leaves and root volume, while the root's dry weight rises with increasing NPK dosage. However, the value of root volume, the leaves number, and the root dry weight are lower when compared to the application of Zeolite given together with NPK fertilizer.

Table 3. Analysis of variance zeolite and NPK Fertilization on growth and P absorption of F. tinctorial

| Parameter          | Source       | Leaf number | Root volume | Root dry weight | Tendril length | P Absorption |
|--------------------|--------------|-------------|-------------|----------------|----------------|--------------|
| Zeolite (Z)        | **           | **          | **          | **             | **             | **           |
| NPK (P)            | **           | ns          | **          | **             | **             | **           |
| Z*P                | *            | **          | ns          | ns             | ns             | ns           |

***/ * = significant at 1% / 5%

The balanced composition of NPK is necessary for vegetative growth. Leaves as an agency of photosynthesis that will produce energy for the development and cultivation of plants. Leaf formation is inseparable from the role of N and P nutrients derived from soil and the addition of NPK fertilizer available to plants [20]. In general, if the plant lacks these nutrients, it can inhibit the formation of new leaves. Plants that do not get nitrogen intake will grow dwarf, and the leaves formed smaller, thinner with a small amount, while plants that get enough nitrogen then the leaves formed will be more and broader [26]. In addition, Zeolite can prevent the loss of NH$_4^+$ cations from organic and inorganic fertilizers by temporarily binding the cations to the cavities of zeolite structures and then re-releasing them. High Al and Fe cations in peat soil that enter holes are held in negatively charged zeolite structures. Anions H$_2$PO$_4^-$ from NPK fertilizer that has not been tied to Al or Fe, finally easily absorbed by the roots of plants. Zeolite also aids the availability of nitrogen in plant root zones because Zeolites also act as slow-release agents for NH$_4^+$ and urea, thus reducing nitrification [14]. In addition, Zeolite raised N and K on the ground [27]. With the increasing availability of nutrients in the soil, NPK absorption may also improve growth, including leaves.

The root dry weight assimilates accumulation at the roots. The root dry weight is significantly affected by zeolite and NPK dosages. Although the dry weight of roots in the media without Zeolite increased markedly by 98% with NPK by 9 g per plant, the dry weight is still lower if NPK is applied together with Zeolite. It is also reported by Milosevic and Milosevic [16], apple growth is better in NPK media applied together with Zeolite or manure. NPK together with palm oil ash also improved the growth of cocoa seedlings in peat soils [28].

Increased root dry weight in zeolite and NPK applications is possible due to the addition of Zeolite increased pH and CEC (Table 2). The addition of NPK further increases the availability of nutrients in the soil and increases nutrient absorption. The application of NPK helps the growth and development of plant root systems. The rooting system in Salvadora persica develops better in NPK application (3:3:3 g + 3 g of nitrogen supplemented as ammonium sulfate) [29]. Growth is influenced both by nutrient intake and by the speed of nutrient transportation. On soils that are approximating a neutral pH, the trend of plant growth increases. With the rise in growth, there will be high assimilation as well.

In the parameters of length tendril, there is no interaction between treatments. Zeolite treatment of 2.5 g polybag$^\dagger$ significantly increased tendril length by 139.7%. The administration of Zeolite has a positive impact on the extension of tendrils. Increased tendrils are possible because the application of NPK increases the development of roots, and a well-developed root system will also achieve better growth of plants and parts. The addition of Zeolite can increase the availability of nutrients [11,25,30] which also allows increased nutrient absorption. Tendril display increased with the addition of fertilization dose, and application of 9 g plant$^\dagger$ increased the length of tendrils by 50.6 % compared to the application of 3 g plant$^\dagger$. 

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$^\dagger$ g: gram; $^\ddagger$: significant at 1%
Table 4. The leaves number, root volume, root dry weight, length tendril and P absorption of *F. tinctoria* on zeolite and NPK fertilizer

| Zeolite (g polybag⁻¹) | NPK (g plant⁻¹) | Leaf number | | | Mean |
|-----------------------|-----------------|-------------|---------------|--------|
|                       | 3               | 6           | 9             | Mean   |
| 0                     | 18.6 a          | 24.7 a      | 31.3 ab       | 24.9   |
| 2.5                   | 35.0 b          | 51.3 bc     | 77.3 c        | 54.5   |
| Mean                  | 26.8            | 38.0        | 54.3          | (+)    |
| Root volume (ml)      |                 |             |               |        |
| 0                     | 68.3 a          | 72.7 a      | 90.3 ab       | 77.1   |
| 2.5                   | 133.0 bc        | 140.7 c     | 121.0 b       | 131.9  |
| Mean                  | 100.65          | 106.7       | 106.15        | (+)    |
| Root dry weight (g)   |                 |             |               |        |
| 0                     | 10.9 a          | 11.8 a      | 21.6 b        | 16.7   |
| 2.5                   | 32.5 bc         | 34.3 c      | 31.7 bc       | 33.4   |
| Mean                  | 23.0            | 24.2        | 27.1          | (+)    |
| Tendril length (cm)   |                 |             |               |        |
| 0                     | 108.0           | 120.7       | 177.7         | 135.4 a|
| 2.5                   | 284.7           | 275.7       | 413.7         | 324.7 b|
| Mean                  | 196.4 a         | 198.2 a     | 295.7 b       | (-)    |
| P absorption (%)      |                 |             |               |        |
| 0                     | 0.097           | 0.153       | 0.147         | 0.132 a|
| 2.5                   | 0.147           | 0.207       | 0.207         | 0.187 b|
| Mean                  | 0.122 a         | 0.180 bc    | 0.177 b       | (-)    |

Note: Dissimilar letters in the same column or row designate the significance among means using Duncan’s multiple range test 5%. Sign (+): interaction Zeolite and NPK; (-): no interaction

3.4. *P absorption*

The application of Zeolite and NPK together does not affect P absorption. Still, the application of NPK and Zeolite independently increases the absorption of P. Zeolite application of 2.5 g polybag⁻¹ increases the absorption of P by 41.3% compared to without application Zn. The availability of P on peat soil is low due to the ability of peat soil in P adsorption P low, so some P is leached. Zeolite can stimulate the breakdown of the bonding of nutrients P with soil cations such as Al and Fe so that the initially unavailable P nutrients become an available form in the soil [31]. Besides that, Zeolite has a characteristic three-dimensional structure and is negatively charged, allowing the exchange of ions to increase the absorption of nutrients P in peat soil [30].

P absorption increases with the addition of NPK dose. NPK application of 6 g plant⁻¹ increased the absorption of P by 47.5%, while at 9 g plant⁻¹ increased by 45%. The increase is possible because NPK increases nutrient availability, so nutrient absorption will also increase. Nevertheless, the increasing P absorption in plants is also influenced by the spread of roots, and the ability of the roots to absorb P. P absorption is highly dependent on the root contact with P in soil solution. The root architecture roots significantly enhance P absorption and plant dry weight. In contrast, P uptake is influenced by the characteristic roots and the availability of P in soil [32].

4. Conclusion

Limited to this research can be concluded that zeolite 2.5 g polybag⁻¹ can increase the pH of peat soil from acid to neutral, tendril length, and absorption P. Zeolite applied with NPK fertilizer increases the number of leaves and root system.

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