



The role of hydrilla (*Hydrilla verticillata* (L.f.) Royle) as soil protectant in improving soil physical, chemical, and biological properties

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Abstract

One of the aquatic weeds inhibiting agricultural production is hydrilla. The plants are simply removed not far from the bunds to prevent them from competing with cultivated plants. However, hydrilla can be used to improve the physical, chemical, and biological properties of the soil. As an indicator of production, chili plants were planted in the trial field in Purworejo Village, Ngantang Sub-district, Malang District from October 2020 to January 2021 to test the dose of hydrilla compost. The treatments tested consisted of hydrilla compost doses of 5 t.ha⁻¹ (P₁), 10 t.ha⁻¹ (P₂), 15 t.ha⁻¹ (P₃), and 20 t.ha⁻¹ (P₄), and NPK (16:16:16) inorganic fertilizer dose of 250 kg.ha⁻¹ (P₅) as control. The experiment was arranged in a randomized block design with three replications. Analysis of variance showed no significant difference ($F < 0.05$) in the number of flower results. Meanwhile, there was a significant effect on the number of fruits, fruit weight, and percentage of flowers into fruits ($F > 0.05$). Hydrilla compost contained 17.3% organic C element, while the inorganic fertilizer contained 4.27%. Hydrilla compost contained decomposing microorganisms, including *Pseudomonas fluorescent* group, *Trichoderma* sp., *Aspergillus* sp. and *Penicillium* sp. The optimum dose of hydrilla compost for chili plants is 20 t.ha⁻¹.

INTRODUCTION

Hydrilla is an aquatic plant that can grow quickly and is widespread throughout the world. Because of its fast growth and development, it becomes one of the problems in waters, making hydrilla commonly called as aquatic weeds (Gettys and Leon, 2021; Marwan et al., 2017; Shiga et al., 2020). Fresh hydrilla plants can act as a carbon source (Jain et al., 2019). Thus, hydrilla biomass can be used as soil carrying capacity, replacing organic fertilizers.

The results of the research showed that the vegetative reproductive structures of hydrilla (tuber and rhizome parts) were able to store carbohydrates (Shi et al., 2021; Fuad et al., 2013; Safitri et al., 2019; Shrivastava dan Sudhakar, 2021). It was also stated that hydrilla contained 3.29% nitrogen (N₂), 0.52%

phosphorus (P₂O₅), and 6.34% potassium oxide (K₂O), in which nitrogen, phosphorus, and potassium are macro elements needed by plants in large quantities to grow and develop (Jain dan Kalamdhad, 2019; Hang, et al., 2019; Hang, et al., 2020). It was stated by Jain and Kalamdhad (2018a) that in the hydrilla decomposition process, a denitrification process occurs, namely the reduction of nitrate to nitrogen gas. Nitrate, which is used as an alternative electron acceptor in anaerobic respiration, is reduced to nitrogen gas, and microorganisms that play a role in the process are Bacillus bacteria (Venkateswarlu et al., 2019). Phytoremediation assisted by bacteria will accelerate the waste degradation process (Si et al., 2020; Sharma et al., 2013; Sousa et al., 2010). Another opinion states that hydrilla can be used for medicine because it contains several active components that

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have potential as anti-oxidants, anti-bacterial, anti-cancer, anti-microbial and anti-tumor (Fasya et al., 2020). Furthermore, it is stated that one of the active components contained in hydrilla is a steroid. The hydrilla plant extract can also be used as an anionic surfactant because based on the results of the phytochemical analysis, it contains alkaloids, phenols, saponins and terpenoids.

So far, farmers have relied on chemical fertilizers, which are considered practical and cheap, because they are subsidized. However, without them realizing it, the excessive use of chemical fertilizers has resulted in soil damage. Moreover, there have been complaints from farmers about the high price of fertilizer. Thus, the use of hydrilla plants as fertilizer can help overcome the problems of farmers about fertilizers.

The purpose of the study was to test the quality of hydrilla as a raw material for compost in increasing the production of chilies and to test how hydrilla compost can be used as a soil protectant.

MATERIALS AND METHODS

The research was conducted in the trial field in Purworejo Village, Ngantang Sub-district, Malang District from October 2020 to January 2021, aiming to test the dose of hydrilla compost (5 t.ha⁻¹ (P₁), 10 t.ha⁻¹ (P₂), 15 t.ha⁻¹ (P₃), and 20 t.ha⁻¹ (P₄)) and NPK (16:16:16) inorganic fertilizer dose of 250 kg.ha⁻¹ (P₅). The experiment was arranged in a randomized block design with three replications.

The composting method commonly used by farmers was combined with research results by Roeswitawati et al. (2019) utilizing rice water washing waste (*leri*)

and molasses. Fresh hydrilla was chopped or cut into small pieces with a size of 5–10 cm, then mixed with rice washing water (*leri*) in a ratio of 1: 1, namely 2 kg of fresh hydrilla mixed with 2 liters *leri*. Then, it was put in a large plastic bag, and the fermentation process took 40 days, marked by the change in the color of hydrilla from green to black and odorless. The chili seedlings cv 'hot beauty' that were 2 weeks old were planted in polybags filled with 5 kg of soil. *Hydrilla verticillata* compost was given according to the treatments. The application of compost and NPK fertilizer (16:16:16) was carried out in stages, namely: 1/3 part was given before planting, 1/3 part was given two weeks after planting, and 1/3 part was given three weeks after planting.

Observations were made on the yield component variables, namely the number of flowers/plants, the number of fruits/plants, the percentage of flowers into fruits, the weight of fruits/plants, and chili yield per hectare. Observations of soil biology (microorganisms) and analysis of soil organic matter were carried out in the rhizosphere 6 weeks after planting, which included nutrient levels (N, P, K). Data analysis performed was analysis of variance and 5% Duncan's test if the results of the analysis of variance showed significant differences. Data analysis was carried out using statistical software Ms. Excel.

RESULTS AND DISCUSSION

Effects of hydrilla compost on the number of flowers, number of fruits, percentage of flowers into fruits, and fruit weight are presented in Figures 1, 2, 3, and 4.

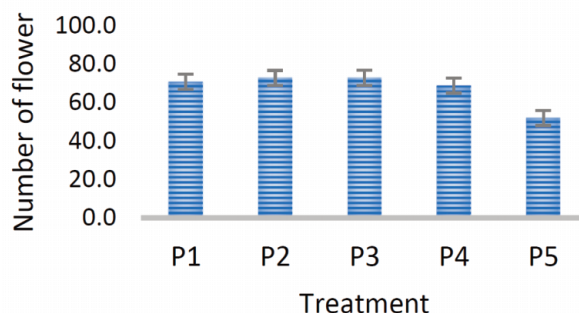


Figure 1. Average number of chili flowers per plant for each treatment of hydrilla compost and NPK inorganic fertilizer treatment (16:16:16)

Remarks: P1 = 5 t.ha⁻¹, STD 0.95; P2 = 10 t.ha⁻¹, STD 1.10; P3 = 15 t.ha⁻¹, STD 0.91; P4 = 20 t.ha⁻¹, STD 1.10; and P5 = 250 kg.ha⁻¹ NPK fertilizer (16:16:16) STD 1.17.

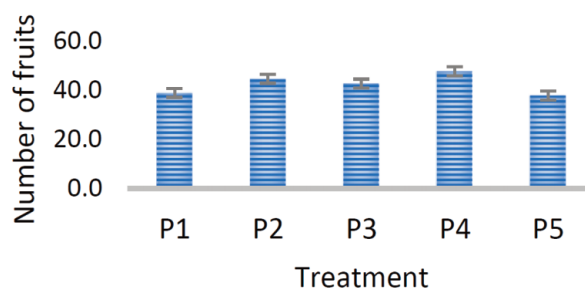


Figure 2. Average number of chili fruits per plant for each treatment of hydrilla compost and NPK inorganic fertilizer treatment (16:16:16).

Remarks: P1 = 5 t.ha⁻¹, STD 0.85; P2 = 10 t.ha⁻¹, STD 0.96; P3 = 15 t.ha⁻¹, STD 1.07; P4 = 20 t.ha⁻¹, STD 1.00; and P5 = 250 kg.ha⁻¹ NPK fertilizer (16:16:16), STD 0.95.

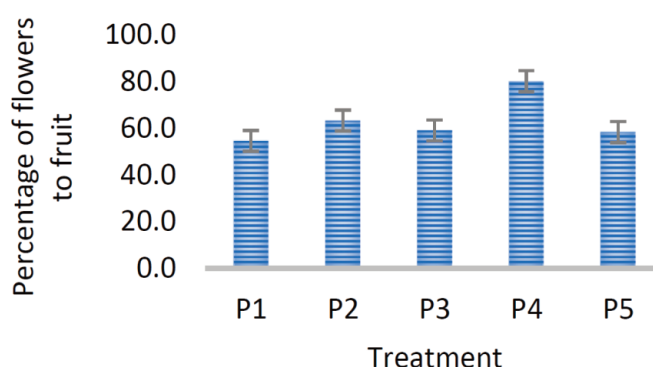


Figure 3. The average percentage of flowers into fruits for each treatment of hydrilla compost and NPK inorganic fertilizer treatment (16:16:16)

Remarks: P1 = 5 t.ha⁻¹, STD 1.00; P2 = 10 t.ha⁻¹, STD 1.03; P3 = 15 t.ha⁻¹, STD 1.04; P4 = 20 t.ha⁻¹, STD 1.53; and P5 = 250 kg.ha⁻¹ NPK fertilizer (16:16:16) STD 1.14.

Number of flowers

Based on the results of the analysis of variance, there was significant effect of the doses of hydrilla compost on the number of flowers compared to P₅ = 250 kg.ha⁻¹ NPK fertilizer (16:16:16), but no significant difference was found between the doses of hydrilla compost. The average values of the number of chili flowers are presented in Figure 1.

Number of fruits

Based on the analysis of variance the number of chilies per plant, there was a significant difference ($P > 0.05$) between the doses of hydrilla compost and NPK inorganic fertilizer (16:16:16). The average values of the number of fruits per plant are presented in Figure 2. In Figure 2, it can be seen that the treatment of P₁ and P₃ were not significantly different ($P < 0.05$) compared to P₅, but significantly different ($P > 0.05$)

compared to P₂ and P₄. The P₂ and P₄ treatments were not significantly different ($P < 0.05$).

Percentage of flowers to fruit

There was a significant difference between the doses of hydrilla compost and NPK inorganic fertilizer (16:16:16). The percentages of flowers into fruits are presented in Figure 3. The results of Duncan's 5% test presented in Figure 3 show that P₁, P₃, and P₅ did not show significant differences, but showing significant difference from P₂ and P₄. Hydrilla compost dose of 20 t.ha⁻¹ (P₄) showed the best effect on the percentage of flowers into fruits.

Fruit weight

There was a significant difference between the doses of hydrilla compost and NPK inorganic fertilizer (16:16:16). The data of fruit weight per plant are

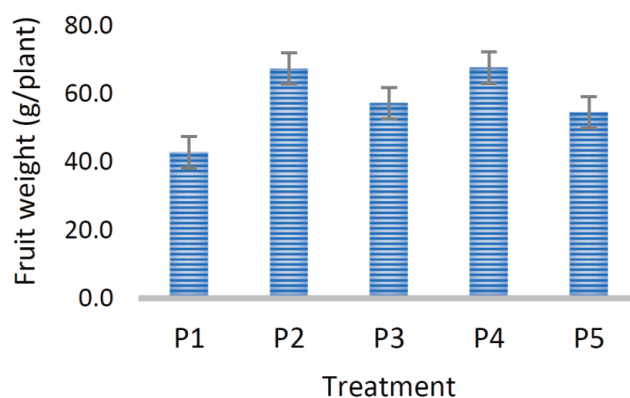


Figure 4. Average chili fruit weight (g/plant) for each treatment of hydrilla compost and NPK inorganic fertilizer treatments (16:16:16)

Remarks: P1 = 5 t.ha⁻¹, STD 1.12; P2 = 10 t.ha⁻¹, STD 1.04; P3 = 15 t.ha⁻¹, STD 1.02; P4 = 20 t.ha⁻¹, STD 1.09; and P5 = 250 kg.ha⁻¹ NPK fertilizer (16:16:16) STD 1.07.

presented in Figure 4. The results of Duncan's 5% test presented in Figure 4 show that the treatment with 15 t.ha⁻¹ (P₃) of hydrilla compost and inorganic NPK fertilizer (16:16:16) did not show significant differences in fruit weight per plant, but significantly different from the treatment with 5 t.ha⁻¹ (P₁), 10 t.ha⁻¹ (P₂) and 20 t.ha⁻¹ (P₄) of hydrilla compost. Treatment of 5 t.ha⁻¹ (P₁) of hydrilla compost showed the lowest fruit weight per plant.

Soil microbiology

Microbial isolation was carried out using the dilution pour plate method (10⁻³.g⁻¹). Identification includes observation of colony morphology, colony color, cell morphology, macroscopic growth. The microbial population density was not calculated, considering that the higher the dose of hydrilla compost given, the more the microbial population, because the role of these microbes is to decompose soil organic matter (Roeswitawati et al., 2018 and Roeswitawati et al., 2019).

The isolation and biological identification of the hydrilla compost showed that the hydrilla compost contained several microorganisms, namely *Pseudomonas fluorescent* group, *Trichoderma* sp., *Aspergillus* sp. and *Penicillium* sp. Whereas in the treatment of inorganic fertilizers, there were no such microorganisms. *Pseudomonas fluorescens* is a bacterium belonging to the antagonistic microbial group, which has round, yellow colony morphology, rod cell shape and gram negative, and motile/has the ability to move. The colonies of *Trichoderma* sp., at first, are white, then

the middle part is light green. Furthermore, the color of the colony becomes dark green in the shape of a circle of clear boundaries. Meanwhile, the edges are white like cotton, and the color of the colony becomes dark green all over the top surface. *Aspergillus* sp. have granular and compact colony morphology and green to yellowish green color. Young colonies are white, and they change color to yellowish green after conidia form. *Penicillium* sp. have a green colony color, the nature of the colony is like velvet, and it has a light brown base color.

Soil analysis

The physical properties of the soil were observed not based on texture, but based on organic matter content. Following is the results of the analysis of nutrient content of N, P, and K from the treatment of hydrilla compost and the treatment of inorganic NPK fertilizer (16:16:16). Land: C = 2.48%; N = 0.19%; C/N = 13.05; Organic Matter = 4.27%; P₂O₅ = 10.95 ppm; K = 0.384 meg⁻¹. Hydrilla compost: C = 10 %; N = 1.13%; C/N = 8.85; Organic Matter = 17.23%; P₂O₅ = 27.8 ppm; K = 0.384 meg⁻¹.

The analysis showed that hydrilla compost contained a very high organic C element, namely 17.3%, while the inorganic fertilizer treatment contained 4.27% organic C element. Organic matter is a source of microbial food to obtain energy because organic C is an essential element in the soil. Based on national standards, hydrilla compost itself has a very high organic C element content (>5%), which is very high.

Discussion

The overall observation results show that the treatment of hydrilla compost fertilizer is better for chili yields than the treatment of inorganic NPK fertilizer (16:16:16) because inorganic fertilizers cannot last longer in the soil compared to compost. This was proven by the results of soil chemical analysis, showing that the NPK nutrient content of the hydrilla compost fertilizer treatment was higher than the NPK nutrient content of the NPK inorganic fertilizer treatment (16:16:16). In addition, the organic C content of hydrilla compost was higher than the organic C in NPK inorganic fertilizer (16:16:16). The results of the analysis showed that hydrilla compost contained a very high organic C element, namely 17.3%, while the inorganic fertilizer treatment contained 4.27% organic C element. Organic matter is a source of microbial food to obtain energy because organic C is an essential element in the soil. Based on national standards, hydrilla compost itself has a very high organic C element content (>5%, which is very high).

Hydrilla verticillata is an organic material that can be used as raw material for making compost (Jain and Kalamdhad, 2019; Hang et al., 2019). Biomass in the soil, both derived from plant and animal remains, will continue to experience changes due to physical, biological and chemical conditions. Thus, it becomes a complex compound and beneficial to plants (Yavitt et al., 2021). The functions of soil organic matter include storing nutrients that will slowly be dissolved in the ground water used by plants. Meanwhile, organic matter on the soil surface can retain soil moisture from high air temperature conditions. The biomass in the soil can increase the carrying capacity of the plants growing on it. Soil organic matter is initially produced by living organisms (plants or animals), which are returned to the soil through a decomposition process (Mosaic Agri Sight, 2021). Soil organic components consist of plant residues and soil organisms/as a decomposer (10–40 %), and stable organic matter/humus (40–60 %).

Hydrilla verticillata compost can improve soil texture so that it becomes fertile with good nutrients because there is a buildup of organic matter, which will increase the ammonia content and decrease the dissolved oxygen content (Si et al., 2020; Sousa et al., 2010). The results showed that *Hydrilla verticillata* was able to act as a remediation of Cu metal contained in electroplating waste (Shi et al., 2021; Lafabrie et

al., 2013). The environment is able to reduce the content of heavy metals in water contaminated with heavy metals. The results of the research showed that *Hydrilla verticillata* as an aquatic weed could be used as a bioremediation by absorbing Cu metal well, namely reducing Cu levels in electroplating waste, because these plants grow below the surface of the water. It was reported that on the surface of the cell walls of young and old leaves of *Hydrilla verticillata* plant growing in waters, there was accumulation of heavy metal Cu. It can be concluded that *Hydrilla verticillata* is able to bind heavy metals contained in wastewater (Jain and Kalamdhad, 2018b). Phytoremediation is one of the uses of plants and their parts to reduce pollution. In hydrilla plant tissues, there is an accumulation of heavy metals contained in wastewater, namely Cu, Zn, and Ni (Kara, 2005). It was reported that the ability of *Hydrilla verticillata* to degrade Cu pollutants in the aquatic environment was up to 43.8%, and the plant was still able to grow well in conditions of 5 ppm Cu solutions. It was also reported that *Hydrilla verticillata* responded to glyphosate solution at a concentration of 80 mg.L⁻¹ (Zhong et al., 2018; Venkateswarlu et al., 2019).

Physical and chemical processes in the soil are directly influenced by a number of soil microbial communities, which drastically cause changes in relation to water availability and nutrient cycling in the soil (Kane, 2019). In waste and soil, it is certain that decomposition occurs, namely the transformation of organic matter, which is eventually mineralized by releasing CO₂ and nutrients mainly carried out by microorganisms (Khatoon et al., 2017). Vegetable waste is soil organic matter that is easily decomposed by microorganisms into compost (Jain et al., 2019). Microbes perform important functions of the soil food web, such as breaking down organic matter, cycling nutrients, and improving soil structure. Bacteria and fungi are the main keys in the decomposition process. Due to the large amount of biomass, on a wide scale, the process is based on the enzymatic capability of the activity of microorganisms. Rhizosphere microorganisms are known to produce components that provide nutrients for plants and promote plant growth (Sharma et al., 2013). It was reported that microorganisms facilitate the uptake of essential elements such as iron, copper and zinc. The rhizosphere microorganism community has potential for the remediation system (reducing pollutants in the

environment) through biotransformation of organic components in the root zone. Soil organic matter contains more than 50 percent carbons. High carbon wasted that has undergone a decomposition process can be useful for agriculture, which can improve crop productivity (Ayaz et al., 2021).

Fungi *Penicillium* sp. and *Trichoderma* sp. are the main cause of spoilage. *Penicillium digitatum* green colony color, in which the nature of the colony is like velvet and has a light brown base color. *Penicillium* sp. is a genus of fungi from the order Hypomycetes, phylum Ascomycota. The hyphae are septate forming spore bodies called conidia. Conidium is different from sporangium because it does not have a protective sheath like sporangium.

There are microorganisms that act as decomposers, namely *Azospirillum*, *Azotobacter*, *Bacillus*, *Aeromonas*, *Aspergillus*, phosphate solubilizing microbes and cellulosic microbes (Yavitt et al., 2021). Organic matter is a medium for the development of microorganisms that is useful for accelerating the decomposition process. *Pseudomonas* sp., *Bacillus* sp., *Streptomyces* sp., *Trichoderma* sp., and *Penicillium* sp. *Streptomyces* sp. can parasitize pathogens. Meanwhile, *Pseudomonas* sp. and *Bacillus* sp. can produce antibiotics and interact negatively against pathogens where the exudate of organic components can lead to hyphae lysis (Kane, 2019).

Natural incorporation of pollutants is the result of the work of microorganisms that are beneficial to plants, such as *Arbuscular Mycorrhizal* fungi, which play a large role in ecological processes (Jain and Kalamdhad, 2018a; Jain and Kalamdhad, 2019). These microorganisms help the host provide phosphorus and nitrogen. *Arbuscular Mycorrhizal* fungi are also beneficial for plants by increasing water uptake for plants (Garg and Chandel, 2010).

CONCLUSIONS

This research shows that hydrilla plant compost is better than inorganic fertilizer NPK (16:16:16) because hydrilla compost contains more N, P, K nutrients and organic C than inorganic fertilizer NPK (16 :16:16) does. The nutrient content of the hydrilla compost is the result of decomposition by microbes, including *Pseudomonas fluorescens* group, *Trichoderma* sp., *Aspergillus* sp. and *Penicillium* sp. A proper dose of hydrilla compost for generative growth and yield of chili plants is 20 t.ha⁻¹.

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