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Sandy and Clay Soil Fertility After Application of Soil Conditioner from Water Hyacinth (*Eichhornia Crassipes* [mart.] solms) Shoots and Roots

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Abstrak

Eceng gondok merupakan tanaman air yang sangat bermasalah. Pertumbuhannya yang cepat akan menyumbat banyak badan air, termasuk di Danau Rawa Pening. Para peneliti sedang mencoba untuk menemukan kegunaan ekonomisnya. Penelitian ini bertujuan untuk mengevaluasi pemanfaatan pucuk dan akar eceng gondok sebagai pembenah tanah dalam meningkatkan kesuburan tanah berpasir dan tanah liat. Kami menggunakan tanah berpasir dan tanah liat sebagai evaluasi dan dua perlakuan kondisioner tanah, menggunakan pucuk eceng gondok dan serbuk kering akar. Biomassa enceng gondok yang diambil dari danau Rawa Pening dikeringkan di bawah sinar matahari dan dihancurkan menjadi bubuk. Serbuk kering dicampur dengan tanah berpasir atau tanah liat disiapkan dalam polybag plastik dengan perbandingan 1:1. Percobaan menggunakan Rancangan Acak Lengkap (RAL). Tanah berpasir dan tanah liat murni tanpa pembenah tanah digunakan sebagai kontrol. Kesuburan tanah campuran dievaluasi untuk bahan organik tanah, populasi bakteri, rasio C:N, dan kapasitas menahan air. Hasil penelitian menunjukkan bahwa pucuk dan akar eceng gondok secara signifikan meningkatkan populasi bahan organik dan bakteri baik di tanah berpasir maupun tanah liat. Rasio C:N berkurang secara signifikan. Kapasitas menahan air di tanah berpasir meningkat secara signifikan, sedangkan di tanah liat berkurang. Penambahan pucuk dan akar eceng gondok sebagai pembenah tanah diduga akan meningkatkan kesuburan tanah berpasir dan liat secara nyata. Akar eceng gondok berkontribusi terhadap kesuburan tanah yang lebih baik daripada pucuknya.

Abstract

Water hyacinth is an aquatic plant that highly problematic. Its fast-growing will chock of many water bodies, including in Rawa Pening Lake. *Researchers are trying to find its economic uses.* This study is aimed to evaluate the use of water hyacinth shoot and root as a soil conditioner in improving the fertility of sandy and clay soil. We used sandy and clay soil as evaluated and two treatments of soil conditioner, using water hyacinth shoots and root dried powder The water hyacinth biomass taken from Rawa Pening lake was dried under the sun and smashed into powder. The mixed dried powder with sandy or clay soil was prepared in the plastic polybag in the proportion of 1:1. The experiment was using a complete randomized design (CRD). Pure sandy and clay soil without soil conditioner was used as controls. Mixed soil fertility was evaluated for soil organic matter, bacteria population, C: N ratio, and water holding capacity. Results indicated that water hyacinth shoots and roots significantly increased the organic matter and bacteria population in both, sandy and clay soil. The ratio of C: N was reduced significantly. Water holding capacity in sandy soil was significantly increased, while in clay soil was reduced. It is suggested that the addition of water hyacinth shoots and roots as soil conditioners will significantly improve sandy and clay soil fertility. Water hyacinth roots contribute to better soil fertility than its shoots.

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PENDAHULUAN

Water hyacinth (*Eichhornia crassipes* (Mart.) Solms), is originated from the Amazon Basin in South America (Minychl et al., 2020). It is a free-floating aquatic plant that is often dominated in a eutrophic freshwater ecosystem. This is a very aggressive invader aquatic plant that capable to form thick mats and cover the entire surface water. It is not only causing anoxia in the water body but also obstructs rivers and favorable for mosquito breeding ground. It will endanger the irrigation of farmland, drainage, water transportation, and human health (Ndimele, 2011). Therefore, strong control of this invasive plant is necessary to manage ecosystem balance. Since 1996, FAO suggests many strategies for water hyacinth controls, including biological, chemical, and mechanical methods. Mechanical controls through removing the entire plant body are easy methods. However, it needs another strategy to reuse and recycle its biomass. The use of aquatic plant biomass for soil conditioner is one of the strategies.

Water hyacinth has been studied for its uses as animal fodder (Tham, et al. 2013); (Mangisah, et al. 2010), fish feed substitution (Zaman, et al. 2017), or green fertilizer (Rahman, et al. 2017). Dwivedi & Dwivedi, (2018) reviewed that water hyacinth is potentially used as valuable products such as biogas, biofertilizer, and bioethanol. These aquatic plants have also been used to produce compost (John, 2016). The use of water hyacinth biomass as a soil conditioner hasn't been deeply studied yet. Soil conditioner is materials that are added to the soil to improve its fertility. This study is aimed to evaluate the effectiveness of water hyacinth biomass as a soil conditioner in improving sandy and clay soil fertility. Sandy and clay soil are less fertile soil. Each has its characteristic properties and responds differently to any treatment. This study will evaluate the response of sandy and clay soil upon soil conditioner from water hyacinth shoots and roots.

MATERIALS AND METHODS

The study is conducted in the greenhouse of the Biology Department, Diponegoro University from August until September 2019. It focused on evaluating and comparing the use of soil conditioners from the shoots and roots of water hyacinth in improving fertility on sandy and clay soil. As water hyacinth commonly has a very massive root system and high in biomass, we evaluate separately between roots. Biomass of water hyacinth is collected from Rawa Pening Lake, located in the Ambarawa Basin, Central Java, Indonesia. The aquatic plants choosen int this study is based on their overpopulation and almost covered the entire surface of the Rawapening lake. Collected biomass was brought to the laboratory and was dried under the sun and continued by crushing into powder. The powder is used as material for soil conditioner. Two types of soil are used as tested media, these were sandy and clay soil. The clay soil was obtained from the area around the campus of Diponegoro University, while sandy soil was taken from the area close to Mount Merapi, Central Java. This two type of soil was chosen to be studied as these two have different characteristics and fertility. This experiment was prepared and design usin CRD (Completed Randomized Design). In this experiment four (4) treatment were applied, i.e: A) sandy soil media with water hyacinth shots dried powder, B) sandy soil media with water hyacinth roots dried powder, C) clay soil with media with dried powder of water hyacinth shoots, D) clay soil media with dried powder of water hyacinth roots. The proportion of soil media to soil conditioner was 1:1. These two materials was thoroughly mixed. The volume of media usesd in each treatment was four-liter (4 L), and was filled into a plastic pot in size of 4 inches (4"). This experiment used 4 replications for each treatment. Data was collected and analyzed with ANOVA.

Parameter Observation

Soil fertility parameters were obsesrved after 7 days. The observation was done by sampling a the mixed media to measure soil fertility improvement. The Walkley-black methods is used to measure soil organic matter. As much as 2 g dried mixed media was taken into a conical flask and added with 10 ml of 1N $K_2Cr_2O_7$ and 10ml of H_2SO_4. Then mixed and cooled for 30 minutes and added with 3 ml diphenylamine as an indicator. The solution of $FeSO_4.7H_2O$ (1N) was used for titration. A solution without sample was us as a blank solution.

The organic carbon in the soil was determined using this formula:

$$C \text{ in soil } (\%) = \frac{[B\text{-}T) \times S \times 0.003 \times 1.3 \times 100]}{W}$$

Where:
B = the amount of $FeSO_4$ required in blank titration,
T = the amount of $FeSO_4$ require in soil titration,
S = the amount of $FeSO_4$ in the from blank solution
W = Soil Organic Matter Weight (%).

The population of bacteria in ech sample was calculated by diluting and plating method. A serial dilution of each sample was plated on agar petri plate. As much as 1 ml of the diluted soil suspension is spread over the surface of the nutrient (peptone yeast) agar plate to allow bacteria growth. The bacteria population in the soil was calculated using the following formula:

The number of bacteria (CFU)
per gram soil = 1/ Dilution factor x number of colony form

The C: N ratio parameter was observed using the combustion method. A combusted sampled used to determine total carbon and nitrogen concentration. The infiltration rate parameter in the sample was observed by pouring 300 ml of water into a 4L volume of sample in a plastic pot with a hole in the bottom of the pot. The period of time used for all water to infiltrate was recorded.

The holding capacity parameter was observed by drying of sample under the sun until a constant weight was achieved and place into a plastic pot with holes in the bottom. As much as 4 liters of water was poured into the soil in the plastic pot. The dropping water out from the plastic pot was collected and its volume was recorded. The collected water dropped was used to calculate the percentage of water that can be held by a certain volume of soil.

The calculation formula is as follows:

$$\text{Percentage of retained water} = \frac{\text{initial weight of water – the weight of dripped water}}{\text{The initial weight of Soil}} \times 100\ \%$$

A completed randomized design (CRD) was used to analyze the collected data. We used 2 types of soil to be evaluated, (i.e., sandy and clay soil), with 2 treatments of soil conditioner (water hyacinth shoots and root dried powder). Pure sandy and clay soil without soil conditioner was used as controls. We apply 4 replication for each treatment. Collected data were analyzed using Anova.

RESULTS AND DISCUSSION (Arial 10)

Soil Organic Matter (SOM)

Results from this study showed that the addition of soil conditioners from water hyacinth significantly increased soil organic matter in both sandy and clay soil ($p<0,05$) (Fig.1).

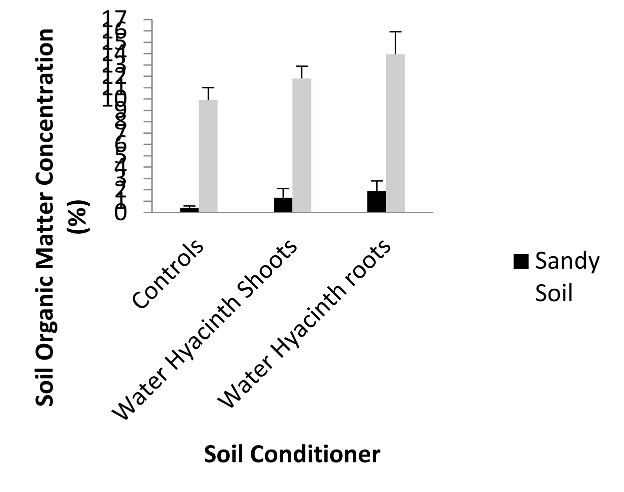

Fig. 1. Organic Matter content of sandy and clay soil after addition of water hyacinth shoots and root powder.

The addition of a soil conditioner is an important step in increasing soil organic matter to improve soil fertility. Before the application of soil conditioner, clay soil already has much higher organic matter than sandy soil. It was approximately contained 9,91 %, while sandy soil only 0,38%. Soil organic matter tends to increase as the clay content increases (Lefèvre, et al. 2017). Soils with higher clay proportion will increase aggregate formation which physically protects organic matter from microbial decomposition.

In sandy soil, the main problem is its low organic matter content. Organic matter and functioning in tropical sandy soils have high implications in its management (Gmach, et al. 2020). It is found from this study that the addition of soil conditioner from water hyacinth shoots into sandy soil increased organic matter almost 3 times (300%). The application of water hyacinth roots resulted in higher organic matter compared to the water hyacinth shoots. This increase was almost 5 times (500%). The roots component of water hyacinth gives more organic matter probably due to the higher content of lignin and cellulose in the roots system. According to Abdel-sabour (2014), water hyacinth roots have more than 7 times of crude fiber content compared to their shoots. Fiber is strongly bonded into lignin and lignocellulose and contains a longer organic carbon chain. This may explain the higher content of organic matter in the soil applied with water hyacinth roots.

In clay soil, the addition of water hyacinth shoots increases organic matter content by approximately 100%, while water hyacinth roots increased by 140%. The higher content of organic matter already in clay soil resulted in only a minor proportion increase after the addition of this soil conditioner. Nevertheless, it may significantly affect its chemical and physical properties. According to Gmach et al. (2020), organic matter is a very important component for soil fertility in determining the chemical and physical properties. Its composition and breakdown rate is key for soil structure, porosity, water infiltration, water holding capacity, biodiversity, and activity of soil organisms. Eventually, it will determine nutrient availability, plant growth, and productivity.

Bacteria Population in Soil

The addition of soil conditioner from water hyacinth shoots and roots resulted in a significant increase of bacteria population in both sandy or clay soil (p <0,05).

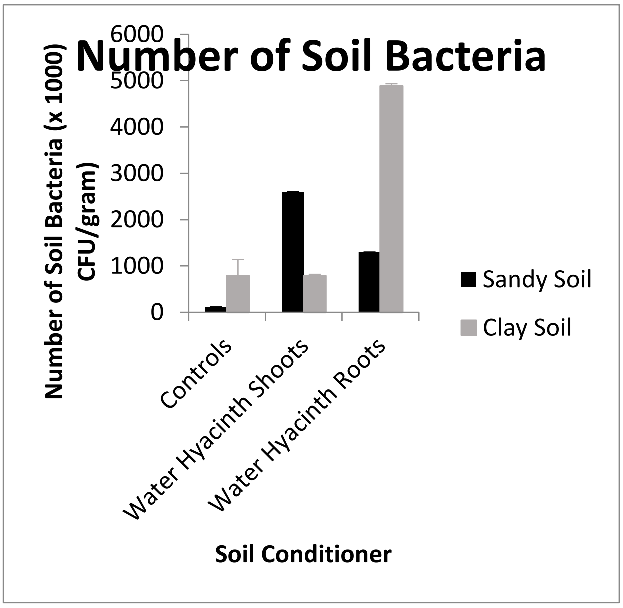

Fig 2. Bacteria number (CFU) in sandy and clay soil after addition by *Water hyacinth* shoots and roots powder.

The bacteria population in pure clay soil is 700% higher compared to pure sandy soil (p<0,05). The higher organic matter content in the clay soil may consider the reason why the bacteria population number was also higher. This organism plays a significant role in the decomposing of organic matter, including soil microbe (Rao et al., 2019).

In sandy soil, the addition of water hyacinth shoots increases the bacteria population by almost 700%, while using water hyacinth roots this increase is much higher (1100%). In clay soil, the use of water hyacinth shoots increases the bacteria population by 300%, while water hyacinth roots increase by 600%. Application of soil conditioner from water hyacinth roots increases the bacteria population more than the addition of water hyacinth shoots. According to Tulika and Mala (2015), water hyacinth has fibrous roots with fine feathery hairs and a purple tinge that functions to capture small particles and removing nutrients from the water column. The higher number of bacteria that live under the soil introduced by water hyacinth root may also be caused by the fact the roots of water hyacinth are a habitat for many macroinvertebrates and small fish (Julie et al., 2014). The presence of this biological mass in the root system may provide protein and other organic components when the roots biomass was sampled and used as a soil conditioner. It is may the reason for increasing the bacteria population in the soil treated with water hyacinth root biomass.

The presence of bacteria in the soil plays a key role as a decomposer. It has been used for a decade to increase plant growth and productivity (Hayat, et al., 2010). A hand full of soil contains millions of microorganisms and plays a crucial role in improving soil fertility and plant growth (Gougoulias, et al. 2014). New nutrients develop in soil due to the biological activity of microorganisms (Kiflu and Beyene, 2013). Through process of decomposition organic matter releases nutrients that will be for plant nutrition (Khatoon, et al., 2017). As decomposers, the number of bacteria will be increased by the application of a soil conditioner.

Ratio of C/N in soil

Results from this study showed that the additional water hyacinth as soil conditioner was significantly lower of C/N ratio on both, sandy and clay soil (p <0,05) (Fig.3).

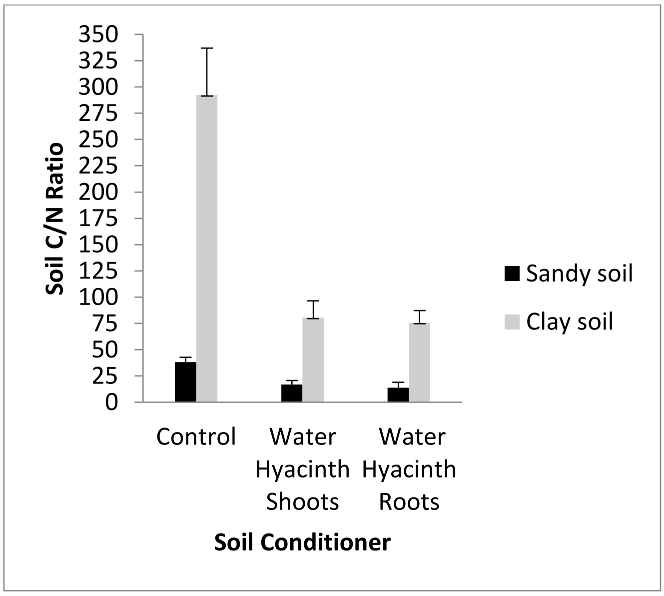

Fig 3. The C/N ratio of sandy and clay soil after the addition of dried water hyacinth shoots and roots powder.

The lower C/N ratio is an indication of a higher portion of Nitrogen in the soil. it is also probably due to the acceleration of carbon decomposition. The shoots of water hyacinth applied into sandy soil reduce C/N ratio from 38,6 to 17,00. It reduced from 100% to 44%. In clay soil, C/N ratio reduction was, even more, it was reduced from 100% to 27% (see fig.3). The application of water hyacinth shoots in clay soil resulted in more mature soil. Maturation in clay soil was faster than sandy soil. it is also because in clay soil the C/N ratio was already high. The C/N ratio is usually used as an indicator of qualitative changes of organic matter decomposition in the soil (Ostrowska and Porebska, 2015).

Application of dried water hyacinth root on sandy soil, reduced the C/N ratio to 34%. This reduction is more effective compared to the application of water hyacinth shoots. A similar trend also resulted in clay soil. The addition of soil conditioner from water hyacinth roots reduces to 25%. It was shown from this study that water hyacinth roots will support more nitrogen than the shoots, and it makes soil becoming more mature and more available to support plant growth. According to Su, et al. (2018), water hyacinth is capable of developing a massive root system and can absorb nutrients in its biomass. The reason why we study using root separate from the shoots was also that it was found that the root system has much more biomass than the shoots themselves. Rezania et al. (2015) reported that water hyacinths growing in swamp areas accounted for 75% of total nitrogen and 75% of total phosphorus removal. This is shown that water hyacinth may rich in nitrogen content. Hereby, It uses for soil conditioner will improve soil fertility. It will increased Nitrogen availability that can support higher plant growth and productivity.

The organic carbon and nitrogen in the soil are key indicators of soil quality (Rezania et al. [2015), It is a crucial indicator to assess carbon and nitrogen balance in the soils (Ge, et al. 2013). It is an indication of soil maturity. More mature soil will have more nitrogen, therefore the C/N ratio will be smaller. This study resulted that the clay soil has a much higher C/N ratio compared to sandy soil. It is found that in controls (soil without conditioner) the ratio of C: N was much higher. Particularly in clay soil the value of the C/N ratio is very high. It was reaching to 292,38, whereas in sandy soil it was only 38,26. According to Jenifer and Hatermink (2019), carbon concentration in clay is commonly higher compared to sand and silt soil. The addition of soil conditioner from aquatic plant biomass must change the C/N ratio, as it contains more nitrogen. A study by Rahman et al. (2017), resulted that the addition of water hyacinth compost in the soil has increased the germination percentage of *Albizia saman*. The growth and yield of Lagos Spinach were also increased (Sanni and Adesina, 2012).

Water Holding Capacity

From this study, we found that sandy soil was taken from the area around Mount Merapi only holds water 3,33%. (Fig. 4). This is a very small amount of water that can behold without pressure.

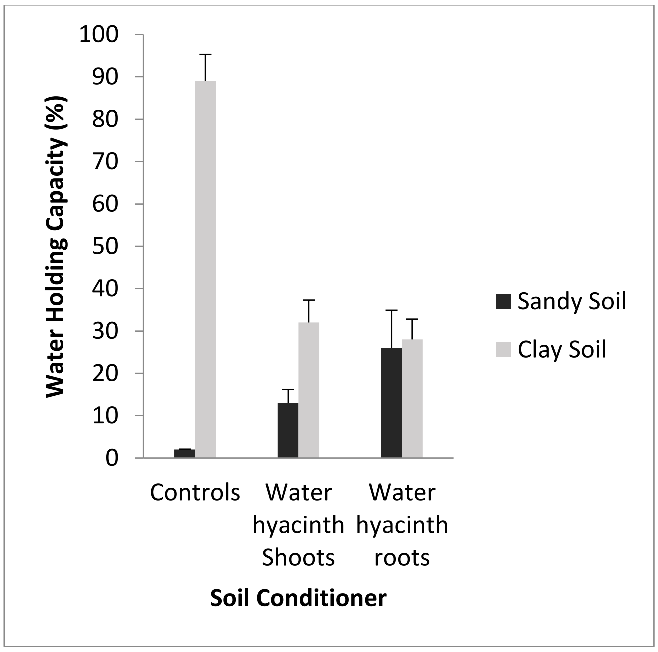

Fig.4. the water-holding capacity of sandy and clay soil after the addition of soil conditioner from Water hyacinth shoots and roots powder.

According to Haridjaja (2013), 85% of sand proportion can hold water to 11,67%. The low capability of holding water in sandy soil that we been studied may because of the higher proportion of big particle size as this type of sand is usually used for construction. Sand that is usually used for construction is mostly composed of large particles measuring 0.02 to 2 mm. Some are considered small gravel. This coarse sandy soil can not hold enough water as it contains more soil macropores.

The amount of water that can behold is a very important factor for plant growth. Soils that can hold a high amount of water can support higher plant growth. It is useful information for determining when plants will be stressed regarding water availability and shortage (Sujatha, et al. 2016). Soil texture plays an important role in determining water holding capacity (Amooh & Bonsu, 2015).

Application of soil conditioner from water hyacinth resulted in a significant increase of water holding capacity in sandy soil. The addition of 50% of water hyacinth shoots increased water holding capacity almost three times while using water hyacinth roots the increase was even more than twice compared to the shoots. Soil water holding capacity is determined by Soil texture and organic matter content (Vengadaramana, 2012,) The organic carbon addition into a sandy soil will more pronounce in increasing soil water holding capacity. For every increase of 1% soil organic matter (% weight), the maximum potential increase of water holding capacity is about 1.5 to 1.7 times (Libohova, 2018). From this study, the increase of water holding capacity is much higher. It may be due to the type of soil conditioner used in this study. The water hyacinth may a type of soil conditioner that significantly capable of increasing water holding capacity, particularly on sandy soil. The increase of water holding capacity in sandy soil indicated that the addition of a soil conditioner will improve soil fertility as sandy soil has extremely low capacity in holding water. The use of water hyacinth roots increases the water holding capacity of sandy soil more than using water hyacinth shoots. The capability of holding water depends on the component contained in the material of the soil conditioner. Water hyacinth roots significantly have a higher content of holocellulose, cellulose, and hemicellulose (Lara-Serrano et al., 2016). The higher content of cellulose water hyacinth roots may explain why soil conditioner application to sandy soil resulted in a higher capability of holding water. According to Hubbe (2015), cellulose and its derivatives can play vital roles as absorbent products and provide structure, water-holding capacity, and channeling of fluids. Higher water holding capacity in the soil will be less subject to leaching losses of nutrients.

On the other hand, clay soil holds too much water. The high water concentration in the soil will reduce the aeration and availability of oxygen. Soil oxygen is crucial for root cell respiration. Soil aeration is one of the key factors in soil fertility parameter and will affect plant growth after water and nutrient concentration. It has been reviewed by Ben-Noah (2018), that soil aeration affects oxygen concentration, which is required by plant roots and soil microbe. Oxygen deficiency will directly restrict plant respiration, nutrient absorption and altering aerobic respiration to fermentation (Neira, 2015).

Results from this study indicated that the soil conditioners application from water hyacinth significantly reduced water holding capacity in the clay soil. According to Libohova (2018), the addition of organic material into the soil can also increase soil porosity. Soil porosity will determine soil aeration, flowing of gases, solutes, and finally will elevate oxygen concentration (Mengistu, 2019; Ben-Noah, 2018). Application of water hyacinth roots reduces more water holding capacity. It can be explained by the higher component of cellulose in water hyacinth roots compare to the shoots. The harder material may capable of providing more macropore in the clay soil. More macropore will provide more oxygen for plant respiration.

CONCLUSIONS AND SUGGESTION

The application of water hyacinth as a soil conditioner increases sandy and clay soil fertility. It is indicated by an increase of organic matter and bacteria population, while the C/N ratio was reduced. There was a different response between sandy and clay soil in the capacity of holding water. The addition of water hyacinth in sandy soil increased water holding capacity, but it was reduced in clay soil. It can be concluded that from all soil fertility parameters observed, there is a strong indication that the addition of water hyacinth as a soil conditioner improves the fertility of both sandy and clay soil. Water hyacinth roots tend to contribute to better soil fertility. This is good information to gain a new economic value of water hyacinth roots, as it has been the most problematic one.

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