Laboratory Incubation Assessment of Amending Phosphate Fertilizers with Rice Straw Biochar in Improving Soil Phosphorus Availability

By

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A report submitted in fulfillment of the requirements for the degree of Bachelor of Applied Science (Agrotechnology) with Honours

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DECLARATION

I hereby declare that the work embodied in this report is the result of the original research and has not been submitted for a higher degree to any universities or institutions

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I centify that the report of this final year project entitled "**Laboratory Incubation Assessment of Amending Phosphate Fertilizers with Rice Straw Biochar in Improving Soil Phosphorus Availability**" by **Nabila Binti Rosdin**, matric number **F14A0159** has been examined and all the correction recommended by examiners have been done for the degree of Bachelor of Applied Science (Agriculture Technology) with Honours, Faculty of Agro-Based Industry, University Malaysia Kelantan.

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ABSTRACT

Phosphorus is an essential plant nutrient and plays important role in carbon uptake also provide many function and superiority. Phosphorus can promote rapid growth of plants and help in develop roots and improve water uptake by roots. Phosphorus deficiency in plants can be identify by observed the changes and abnormalities that shown by the plants. Major problem phosphorus deficiency in soil is phosphorus fixation. Phosphorus fixation is where volume of phosphorus in the soil decreases due to the presence of aluminum and irons. The objectives of this study were to characterize the selected physic-chemical properties of soil sample and rice straw biochar, and to determine the soil phosphorus availability upon amending phosphorus fertilizer with rice straw biochar in a laboratory incubation study. An incubation study was conducted at laboratory at University Malaysia Kelantan, Jeli Campus. Rice straw biochar were used in the treatments. Treatments with mixture of rice straw biochar showed significantly increase in soil pH for 30 days, 60 days and 90 days. Besides, significant reduction of exchangeable acidity, aluminum and iron in the soils compared to treatments with chemical fertilizer and soil only. Furthermore, there also significant increase in phosphorus availability in treatments amended with rice straw biochar for 30 days of incubation. This was due to reduction of soil exchangeable acidity, aluminum and iron concentration, thus increase the phosphorus availability in the soil. As a conclusion, biochar derived from rice straw can be used to improve phosphorus availability in acid soils by reducing the soil phosphorus fixation.

Key words : Phosphorus Fixation; Laboratory Incubation Study; Rice Straw Biochar; Soil pH; Egypt Rock Phosphate..

Penilaian Inkubasi Makmal tentang Meminda Baja Fosfat dengan Biochar Jerami dalam Meningkatkan Ketersediaan Fosforus dalam Tanah.

ABSTRAK

Fosforus merupakan nutrisi tumbuhan yang penting dan memainkan fungsi penting dalam pengambilan karbon serta menyediakan banyak fungsi dan kelebihan. Fosforus boleh mempercepatkan tumbesaran pokok dan membantu dalam pertumbuhan akar serta meningkatkan pengambilan air oleh akar. Kekurangan fosforus pada tumbuhan boleh dikenal pasti dengan melihat perubahan dan keanehan yang ditunjukkan oleh tumbuhan. Masalah utama kekurangan fosforus dalam tanah adalah penetapan fosforus. Penetapan fosforus adalah dimana jumlah fosforus dalam tanah berkurangan disebabkan oleh kehadiran aluminium dan besi. Objektif untuk kajian ini adalah mengambarkan sifat fizik-kimia untuk sampel tanah serta biochar jerami dan untuk menentukan ketersediaan fosforus dalam tanah apabila meminda baja fosforus dengan biochar jerami dalam kajian inkubasi makmal. Kajian inkubasi ini dijalankan di makmal bertempat di Universiti Malaysia Kelantan, Kampus Jeli. Biochar jerami telah digunakan dalam rawatan ini. Rawatan yang mempunyai campuran biochar jerami menunjukkan peningkatan signifikan dalan pH tanah pada hari ke 30 inkubasi. Selain itu, pengurangan signifikan pada pengantian keasidan, aluminium serta besi dalam tanah berbanding dengan rawatan yang mempunyai baja kimia serta tanah sahaja. Disamping itu, terdapat peningkatan signifikan dalam ketersediaan fosforus pada rawatan yang dicampur biochar jerami pada hari ke 30 inkubasi. Ini disebabkan oleh pengurangan kepekatan pengantian keasidan, aluminium dan besi yang menyebabkan peningkatan dalam ketersediaan fosforus dalam tanah. Kesimpulannya, biochar berasaskan jerami boleh digunakan dalam meningkatkan ketersediaan fosforus dalam tanah yang berasid dengan mengurangkan penetapan fosforus.

Kata kunci : Penetapan Fosforus, Kajian Inkubasi Makmal, Biochar Jerami, pH tanah, Mesir Fosfat Batu.

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LIST OF ABBREVIATIONS AND SYMBOLS

P	Phosphorus
H	Hydrogen
N	Nitrogen
K	Potassium
C	Carbon
Na	Sodium
Fe	Iron
Al	Aluminum
OH	Hydroxide
Mg	Magnesium
Ca	Calcium
Cu	Copper
Zn	Zinc
$H_2PO_4^-$, HPO_4^{2-}	Orthophosphate
NaOH	Sodium hydroxide
HCL	Hydrochloric acid
H_2SO_4	Sulphuric acid
CO_2	Carbon dioxide

KCL	Potassium chloride
pH	Potential of hydrogen
EC	Electrical conductivity
CEC	Cation exchange capacity
ATP	Adenosine triphosphate
ERP	Egypt rock phosphate
VAM	Vesicular arbuscular mycorrhiza
DAI	Days incubation
ANOVA	Analysis of variance
SPSS	Statistical package for social science
ITMA	Institute of Advance Technology
UPM	University Putra Malaysia
MARDI	Malaysian Agricultural Research and Development Institute

Chapter 1

Introduction

1.1 Research Background

1.1.1 Background

Phosphorus (P) is an essential plant nutrient and limiting nutrient for terrestrial productivity. Phosphorus is very important because it plays a key role in the net of carbon uptake in terrestrial uptake and provides many function and superiority towards plants (Prasad, Lal & Prasad, 2016). Phosphorus is an macro nutrient where the single most restricting element for plant production (Antoniadis, Koliniati, Efstratiou, Golia & Petropoulus, 2015). A study by Roberts and Johnston (2015) revealed that P is part of genetic material such as genes and chromosomes where involves in process for plant reproductions and cell divisions.

Besides, P can be used in storing energy and transferring energy in all living things. It is very essential because all the biochemical reaction will stop without the presence of P (Filippelli, 2016). In additions, P is also beneficial to the plants. A study by Maguire (2014) discovered that P can promote early and rapid growth for plants. Phosphorus can help in enhancing young seedlings to grow more faster. Secondly, P can help to develop roots and improve the water uptake by roots (Kruse et al., 2015). Next, P enhances the speed of maturity of crops, thus the crops can be harvested in short time. In addition, P can improve the fruits quality and grains (Grant, Flaten, Tomasiewicz & Sheppard, 2000).

When the soil suffers P deficiency, the plants will show several symptoms. A study by Grant, Flaten, Tomasiewicz and Sheppard (2000) concluded that P deficiency will result in a decreased plant height, delayed of leaf emergence and phasic development, and reduction in secondary root development, seed production and tillering. Second symptom is the plants will develop purple tint at the leaves and stem (Prasad, Lal & Prasad, 2016). Phosphorus deficiency will delay the maturity of crops such as corn and soybean (Maguire, 2014). Most of the soil for agriculture use in Malaysia is lack of P. The P deficiency becomes a serious problem to the farmers. This is due to P fixation, where P fixations allows only small portion of P to be taken up by the plants (Arai & Livi, 2012).

The process usually involves complexation of phosphate anions from the applied fertilizers with iron (Fe) and aluminum (Al) hydroxide present in the soil and clay particles (Prasad, Shivay, Majumdar & Prasad, 2016). In soils, pH influences the amounts and forms of P in the soils (Turner & Blackwell, 2013). Phosphorus usually available to the crops at soil pH of 6 and 7 (Ch'ng, Ahmed & Majid, 2014). Phosphorus availability in soils will decrease when the soils become too acidic. When the soils become too acidic, it will enhance the P fixation and volume of P in soils will decrease due to the presence of Al and Fe ions (Margenot, Singh, Rao & Sommer, 2016).

The common practice used by the farmer to overcome this problem is to lime the soil. The farmer will apply the lime on the acidic soils to increase the soil pH from acidic to neutral. The lime will reduces the concentration of H^+ ions and will increase the concentration of OH^- ions by adding non-acid forming cations. Another common practice used by the farmer is application of excess chemical fertilizer. However, this practice is not economically and not environmental friendly because it will cause pollution to the ecosystems such as eutrophication (Prasad, Shivay, Majumdar & Prasad, 2016). From that, it will promote the growth of algal blooms. When there is too much algal bloom in the water, the total dissolved oxygen in the water will decrease, and the aquatic life will die due to lack of dissolved oxygen in the water.

Paddy is suitable to be cultivated in tropical wet region like Malaysia. About 300,500 hectares of land were used in Malaysia for paddy cultivated. The temperature and the rainfall distribution in the country are suitable for year round cultivation of rice. However, most farmers plant and harvest rice more or less during the same period. Rice straw waste can be used as permanent soil cover or mulching, where the rice straws are placed on the soil as cover to prevent soil erosion. It can be used as additional fertilizer to soil (Hussain et al., 2016). According to Dobermann and Fairhust (2002), burning of the rice straw can cause atmospheric pollution and resulting in nutrient loss, but it is very effective in reducing pest and disease population.

Biochar is the material produced when undergoes any chemical processes under the conditions of pyrolysis or gasification, process that heat biomass in the absence or reduction of oxygen (Faucon, Houben, Reynoird, Dulaurent, Armand & Lambers, 2015). Biochar are mostly alkaline where the pH value is more than 7. Biochar is often being used to increase the pH of acidic soils as it affects the mobility of cations in the soils (Mukome & Parikh, 2016).

Besides, biochar is very useful in improving soil chemical and physical properties. Biochar can increase the cation exchange capacity (CEC), pH, water retention to improve nutrient retention and bioavailability (Amin, Huang, He, Zhang, Liu & Chen, 2016). Next, biochar has porous environment for fungi and bacteria as physically protected habitat from large predators and alteration of allelochemical signaling dynamics between plants roots and also colonizing microorganism within the rhizosphere (Uchimiya, 2016).

1.1.2 Problem Statement

Major problem of P deficiency in soil is P fixation. Phosphorus fixation is where the volume of P in the soil deceases due to the presence of Al and Fe.

However, there is dearth information on the conversion of rice straw biochar to enhance P availability in the soil.

1.1.3 Research Question

If P deficiency is soil were cause by P fixation, would if not be possible that biochar derived from rice straw reduced the P fixation thus increase the P availability in the soil?

1.1.4 Hypothesis

The hypothesis in this study via laboratory incubation is the soil available P increases by amending P fertilizers with biochar derived from rice straw.

1.1.5 Objectives

Thus, the objectives of this study are as follows:

1. To characterize the selected physico-chemical properties of soil sample and rice straw biochar.

2. To determine the soil P availability upon amending P inorganic fertilizer with rice straw biochar in a laboratory incubation study.

1.1.6 Scope of Study

This study focuses on a way to improve P availability in soil by amending P fertilizer with rice straw biochar.

1.1.7 Significant of Study

Application of rice straw biochar will help in increasing the P availability in soil. By using rice straw as biochar, it can reduced the pollution and waste of rice straw can be manage properly.

Chapter 2

Literature review

2.1 Phosphorus cycle

The main source of P is *via* weathering process during soil development. Differ from chemical weathering, the physical weathering and erosion material from the continents result in P that is unavailable to biota. Phosphorus and other compound will rapidly undergo weathering if the fine material deposited in environment undergoes chemical weathering and soil development (Filippelli, 2016). Most of the reservoir of P are in sedimentary rock *via* weathering and then it is distributed to the soil and water. Plants will take up the P ions from the soil. Then P moves from plants to animal. Animal tissue absorbs P through consumption, then return back to soil through excretion of urine and feces (Boundless, 2016). When plants material are returned back into the soil, this organic P will be released slowly as inorganic P and becomes soil organic matter. This process that releases inorganic P from organic P is called as mineralization (Busman, Lamb, Randal, Rehm & Schmitt, 2002).

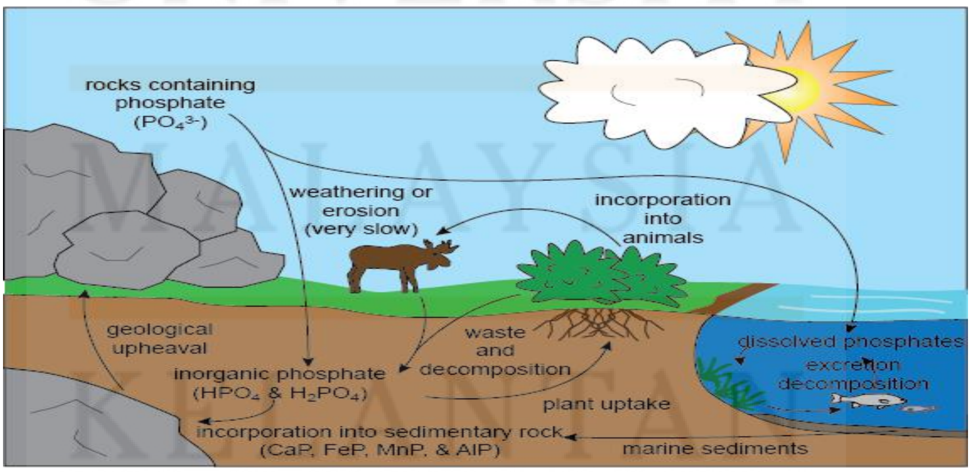


Figure 2.1 : The phosphorus cycle.

(source :http://www.shmoop.com/ecology/phosphorus-cycle.html)

Same process will occur in aquatic ecosystem. When there is runoff of the water on the soil particles, P will be leached out because P is not highly soluble (Kruse et al., 2015). According to Zhang, Tan, Wang, Ma and Welacky (2016), tillage practice in soil will result in P leaching from the soil. Then P will settle down at the bottom of the oceans and also bottom of the lake. After that, P will enhance the growth of plankton and plants and it will favors the growth of weeds known as eutrophication (Filippelli, 2016). Excessive growth of the weeds and plants will consume large number of dissolved oxygen in water. So the total dissolved oxygen inside the water will become less for the fish and other marine animals consumption (Boundless, 2016).

2.2 Forms of Phosphorus

2.2.1 Organic Phosphorus

Organic P may vary from 20 to 65% or even more of the total P, where the higher value are usually found in organic soils (Prasad, Shivay, Majumdar & Prasad, 2016). The texture of soil, fertilizer, drainage and other factors will affect the organic P content in the soil. Soil P will present as organic P in organic soils and peat soil rather than in mineral soils. In mineral soils, high clay soils have greater percentage of P in organic form than sandy soils. It is where clay minerals will adsorb the enzyme phosphate to inhibit hydrolysis of phosphate esters. So the smectites will provide large high surface areas for the adsorption of substrate and enzyme phosphatase and exchange cation will lead to accumulation of organic P (Prasad, Shivay, Majumdar & Prasad, 2016). Soils that derived from basalt and basic igneous parent materials will contain higher amount of organic P compared to granite. Temperature also becomes one of the factors that might affect the soil organic P because it will affect the growth of microorganisms that are responsible for immobilization and mineralization of P in the soils. The colder climate region will contain more organic P than hotter climate region.

2.2.2 Inorganic Phosphorus

Inorganic P in soils mostly can be found in the form of Ca, Fe, and Al phosphate. Inorganic P contain Ca phosphate which dominates in neutral to alkaline soils while Al and Fe phosphates dominate acidic soils. Inorganic P in the ionic form are dependent towards pH. When the value of pH is around 4.0 to 6.0, most of the P in soils present as $H_2PO^-_4$ which is available for plants uptake because they are water soluble (Prasad, Shivay, Majumdar & Prasad, 2016). When the pH value is below 3.0, there will be plenty of soluble Fe and Al in the soils that will react with P to form insoluble P that cannot be taken up by plants.

2.2.3 Soluble Phosphorus pool

Size of the P solution usually very small and will contain only a fraction of a pond of P per acre. Soluble P pool will be in orthophosphate form but small amount of organic P will exist as well. Besides, plants will take up P in orthophosphate form. Soluble P pool is important because it is the pool of P available for plant uptake (Busman, Lamb, Randal, Rehm & Schmitt, 2002). During the growing seasons, most of the P are taken up by the plants that will move only an inch or less through the soils to the roots. If the soluble P is not being continuously replenished, the growing crop will quickly deplete the P.

2.2.4 Active Phosphorus pool

Active P pool is where the P will be easily released to the soil solution. Concentration of P will decrease because plants will take up P. So some of the P from active P pool will be released, because active P pool is the main source of available P for plants and crops. Active P pool has an ability to replenish soil solution

P pool. (Busman, Lamb, Randal, Rehm & Schmitt, 2002). Phosphate will react with elements like Ca or Al to form soluble solids and organic P easily mineralized (Kruse et al., 2015).

2.2.5 Fixed Phosphorus pool

Fixed P pool contains inorganic P compound that is very insoluble and organic compound that is resistant to mineralization by microorganism in soil (Busman, Lamb, Randal, Rehm & Schmitt, 2002). Phosphate in this type of pools will remain years in soils without being available to plants. Inorganic compounds in fixed P pool has more crystalline in structure and less soluble.

2.3 Functions of Phosphorus

Phosphorus is very important to plants because it will help in cell and development of new tissues. Phosphorus is also associated with complex energy transformations in plants. By adding P in soil, it will promote early and rapid growth for small seedlings. Second, P will help roots of young plants to develop because some of the soil might be hard for roots of young plants to penetrate in order to get water and nutrient supply (Grant, Flaten, Tomasiewicz & Sheppard, 2000). So P will help young plants root to develop and make it easier to obtain water and nutrient supply.

Besides, P also improves water and nutrient absorption for plants use. In addition, P plays important roles in photosynthesis. It will utilize light energy with the presence of chlorophyll to produce sugar with the energy that being captured by ATP (Prasad, Lal & Prasad, 2016). A study by Margenot, Singh, Rao and Sommer (2006) reported that P involves in energy transfer process where the ADP and ATP will transfer the high energy P to the other molecules. Phosphorus also can be used as genetic transfer because P becomes important component that build blocks of genes and chromosome and will help in carrying genetic code from one generation to the next (Filippelli, 2016).

2.4 Movement of Phosphorus

2.4.1 Movement of Phosphorus in plants

Plants take up P from soil in orthophosphate ions, namely HPO_4^{2-} or $H^2PO_4^-$. However the degree of absorption depends on soil pH (Kruse et al., 2015). When the soil pH is acidic, more HPO_4^{2-} is taken up. However, most $H_2PO_4^-$ is taken up with the help of cotransport (Prasad, Lal & Prasad, 2016). Furthermore, the absorption of soil P by plants depends on its root characteristics and its capacity to release organic acids. Root mycorrhizal also contribute to the increase of soil P accessibility by plants. Mycorrhizal has two pathways for P uptake. First is *via* soil root interface and second is *via* vesicular arbuscular mycorrhiza (VAM) hyphae (Prasad, Lal & Prasad, 2016). Orthophosphate ions will be transported in xylem to younger leaves once it is being absorbed. The $H_2PO_4^-$ from older leaves also will move to younger leaves and some from the shoots to the roots.

2.4.2 Movement of Phosphorus In soil

In soils, P moves very little in mineral soils but leaches out from organic solids such as peat. It is because P never moves very fast in mineral soils due to clay (Prasad, Shivay, Majumdar & Prasad, 2016)

2.5 Presence Concerns of Phosphorus Fixation

Once water soluble P is applied on soil, it will start to react with the soil constituents and is precipitated or retained by soil. Phosphors will retain in soil by hydroxides and oxyhydroxides of Fe and Al, silicate minerals, carbonates and soil organic matter. There are four steps involved in the precipitation process when dissolved P reacts with soil. The first step is formation of a surface adsorbed P complex. Second is the dissolution of clay minerals that will increase the P reactive metal ion concentration in the solution (Figure 2.2).

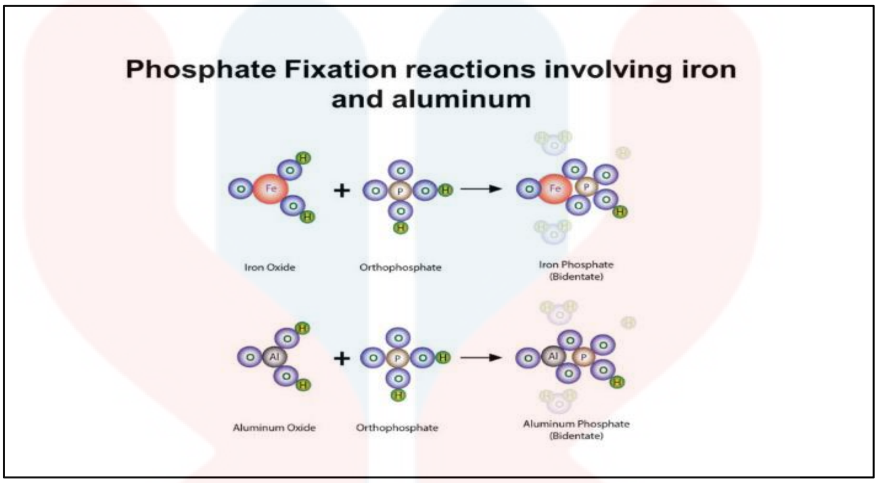


Figure 2.2 : Phosphate fixation reactions involving iron and aluminum.

(Source : http://www.numeratortech.com/tech_info/Phosphorus_Fixation1.pdf)

Third is where slow desorption of surface adsorbed P compounds and fourth where slow nucleation, crystallization , and recrystallization of P compounds. (Margenot, Singh, Rao, Sommer, 2016). Furthermore, P sorption is affected by the type of surface P contacted in the soil. Amorphous Fe and Al oxides are most effective P sorbents due to their high specific surface area and sorbents (Margenot, Singh, Rao & Sommer, 2016) (Figure 2.3).

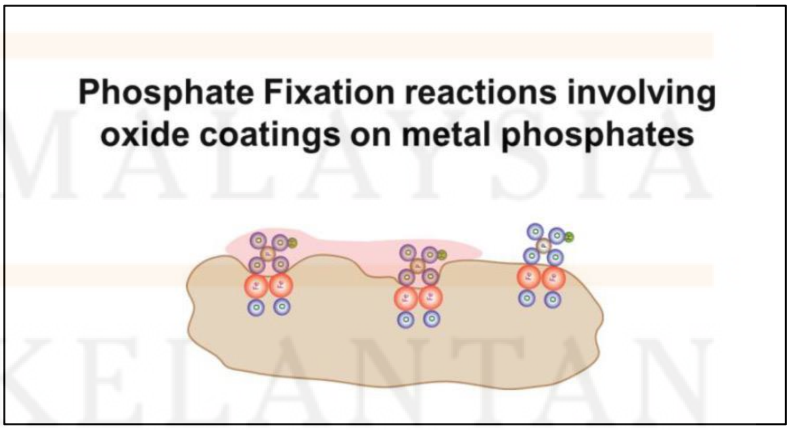


Figure 2.3 : Phosphate fixation reaction involving oxide coating on metal phosphate.

(Source : http://www.numeratortech.com/tech_info/Phosphorus_Fixation1.pdf)

2.6 Factors affecting Phosphorus availability in soil

2.6.1 Amount and type of clay

Soils that contain high content of clay will fix P more that soil containing less clay. Soils that has certain type of clay minerals like kaolinite, Al, Fe oxides and hydroxides and amorphous clay minerals will retain or fix more P than other soils (Prasad, Shivay, Majumdar & Prasad, 2016).

2.6.2 Compaction

A study by Yuksek, Kurdoglu & Yuksek (2010) reported that soil compaction will reduce soil infiltrability and permeability. Soil compaction also reduce the aeration and pore space that is available in root zone. This will reduce the P uptake by the plants. The roots of the plants cannot penetrate well and cannot efficiently undergo nutrient and water uptake by plants (Busman, Lamb, Randal, Rehm & Schmitt, 2002).

2.6.3 Soil pH

Plants will uptake P from the soil solution in the form of orthophosphate, namely $H_2PO_4^-$ and HPO_4^{2-} , depending on the soil solution pH. Phosphates that are anions can bind to positively charge binding sites of the soil minerals and soil organic matter surface (Margenot, Singh, Rao & Sommer, 2016).

Phosphorus are available for crops uptake when the soil pH value are at 6 and 7 but when the soil pH is less than 6, P deficiency will increase in most crops (Ch'ng, Ahmed & Majid, 2014). When the soil pH is too acidic, the P availability in soil will reduce. When the soil pH is too acidic, P fixation will occur. Soil pH that has value between 6 and 7 are very ideal for P availability while the pH value below 5 and between 7 and 8 limits P availability to plants due to P fixation by Al, Fe and Ca.

A study by Arai & Livi (2012) discovered that when pH value ranges between 4 and 8, negatively charge P ions $H_2PO_4^-$ and HPO_4^{2-} are strongly retain on charge mineral surface at acidic pH and will gradually decreasing as the volume of pH increasing. According to Margenot, Singh, Rao and Sommer (2016), the maximum adsorption of Kaoline at pH value 4 to 5 decrease rapidly when the pH is above 6, while P sorption to ion (hydr)oxide geothite is maximized at pH 5 to 6 and will decrease to 60% at pH 9 (Figure 2.4). The surface area effects were critical because it will increase the binding sites of plant availability inorganic P. Thus amorphous Fe and Al have greater surface area than crystalline form that will have greater P retention potential (Prasad, Shivay, Majumdar & Prasad, 2016). A study by Margenot, Singh, Rao and Sommer (2016) revealed that soil organic matter can exhibit pH dependent binding sites for P and anions which can influence P sorption at high soil organic matter levels and low pH value.

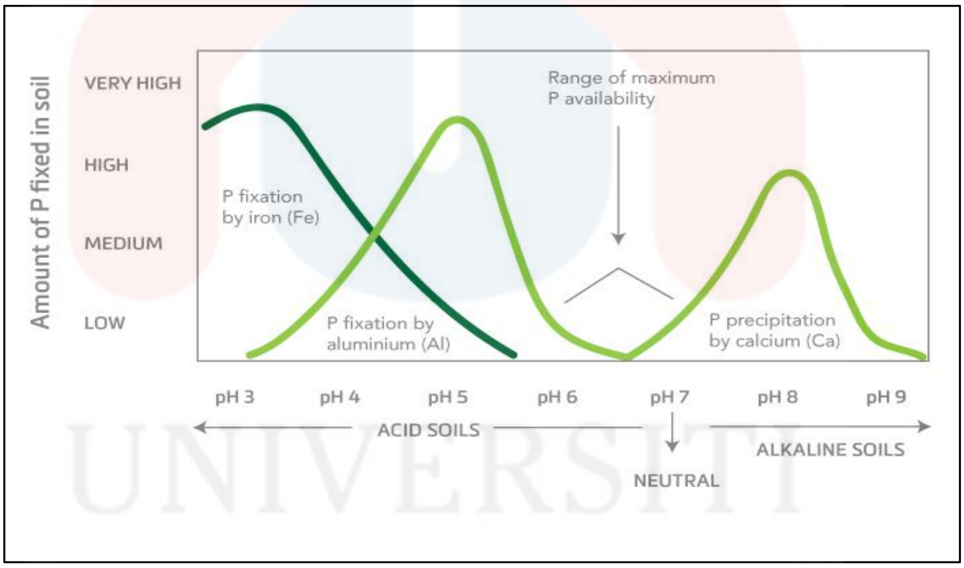


Figure 2.4 : Graph of pH value that influence the P availability in soils.
(source:http://crystalgreen.com/agriculture/)

2.7 Common practices of solving phosphorus fixation

2.7.1 Liming

Lime can be used to improve the availability of P in soil by increasing the soil pH because mineral oxide binding to P decreases as the pH increases. Liming has it own potential in improving agricultural production on weathered soils like Oxisols. Besides, liming rates can be determined by soil pH, base saturation or Al saturation (Margenot, Singh, Rao & Sommer, 2016). Liming can be used to reduce the Al and Fe, but not economical because over liming cause P fixation too which is concentrations Ca phosphate and excessive use of P fertilizers can cause eutrophication (Ch'ng, Ahmed & Majid, 2014).

2.7.2 Application of fertilizer

A study by Maguire, (2014) revealed that increasing soil P concentration can be done by using any type material that contain P such as fertilizer, manure, composted material and biosolid. Phosphorus fertilization can be done by application of chemical fertilizer that were derived from phosphate rock to fullfill crop requirement for growth (Faucon, Houben, Reynoird, Dulaurent, Armand & Lambers, 2015). When a fertilizer contains water soluble P is being added to the soil, only small proportion is remained in the soil and some of it will be available for plants uptake (Margenot, Singh, Rao & Sommer, 2016). When apply excess fertilizers, some of the phosphate will bind with Al^{3+}, while the remaining of the phosphate will be readily available for plants uptake. But when too much fertilizers are being applied, the amount of phosphate increases and exerts higher risk of soil run off and leaching (Yuksek, Kurdoglu, & Yuksek, 2010).

2.8 Rice cultivation and paddy waste generating

According to Karim, Man and Sahid (2004), paddy cultivation in Peninsular Malaysia covers an area about 209,300 ha where at Muda in Kedah is the largest (98,860 ha), Kemubu in Kelantan (32,400 ha), Kerian in Perak (24,010 ha), Projek Barat Laut Selangor (19,920 ha), Seberang Perak in Perak (6,510 ha), Besut in Terengganu (5,100 ha) and Seberang Perai n Penang (1,300 ha). While in Sabah, the total area of rice planted area is 44,921 hectares. This will produce 2.7 tonnes of rice per hectare (Daily Express, 2015).

Thus, when the production increases, the waste of the paddy also will also increase. Rice straw is one of the wastes that are produced from the paddy production. Most farmers will manage this waste by burning. This is not environmental friendly because it will cause pollution. Burning also cause atmospheric pollution and will lead to nutrient loss (Dobermann, & Fairhust, 2002). To manage these problem, rice straw can be used as an ingredient for cocopeat. Addition of rice straw in cocopeat will increase the amount of nutrient in the cocopeat for plants uptake as the cocopeat becomes the media for plants growth (Marjenah, Kiswanto, Purwanti, & Sofyan, 2016). Moreover, rice straw can be used as fuel for cooking, ruminant fodder, and aslo become raw material for industrial processes like paper making (Dobermann, & Fairhust, 2002)

2.9 Biochar

2.9.1 Process of biochar production

There are four types of biochar production process, namely slow and fast pyrolsis, torrefaction, gasification and hydrochar.

2.9.1.1 Slow and fast pyrolysis

Biochar production under dry conditions and slow pyrolysis is the most efficient. It begins with biomass heated slowly about 500 °C with absence of air over long period. Slow pyrolysis yields a high carbon, energy dense solid char product (Kunhikrishnan et al., 2016). While for fast pyrolysis requires dry biomass (<10 wt% moisture), rapid heat transfer, fast temperature increase by heating small biomass particles to 400 – 500 °C and vapor residence times of 1 second but maximum 5 second.

2.9.1.2 Torrefaction

It is thermorchemical treatment process carried out at temperature range of 200 – 300 °C in a nonoxidative environment to improve the physical and chemical characteristics of biomass also aid in further conversion to biofuels. This can be done by facilitating decomposition early degraded volatile matter and repolymerization of cellulose and lignin. This torrefied biomass resembles the original material in shape and size but it is darker, friable and hydrophobic with higher calorific content. Mild pyrolysis is used in energy densification. Hemicellulose, cellulose and lignin content of biomass are partly decomposed depending on the torrefaction temperature and biomass residence time in reactor. The advantages of torrefaction are higher energy density and heating value., reduce transport cost due to reduced moisture of the end product, higher resistivity of torrefied biomass to the hydrophobic nature, reduce grinding energy requirements, and creation of the more uniform fuel for gasification or cofiring for electricity (Kunhikrishnan et al., 2016). This process does not produce adsorbent chars because only partial biomass decomposition occurs to prevent decay and induce some water loss.

2.9.1.3 Gasification

It takes place at much higher temperature than pyrolysis and torrefaction. It produces clean gas that can be used in internal combustion engines or to produces electricity. The energy in biomass or any other organic matter is converted to combustible gases where it is the mixture of carbon monoxides, methane and hydrogen gas at temperature from 600 ^{o}C to 1000 ^{o}C with char, water and condensable tar as minor products (Kunhikrishnan et al., 2016). Furthermore, gasification is performed under a partially oxidizing atmosphere.

2.9.1.4 Hydrochar

It refers to solid product from hydrothermal carbonization of carbon rich biomass in the presence of water called hydrous pyrolysis. The hydrothermal carbonization process usually takes place at relatively low temperature at 150 ^{o}C to 350 ^{o}C and under high pressure. It can be applied directly towards wet feedstocks such as wet animal manure, sewage sludge and algae (Kunhikrishnan et al., 2016). This process does not require an energy insentive predying steps. Moreover, hydrochar process is eco friendly because does not generate any harzadous chemical waste or by products as does dry pyrolysis.

2.9.2 Usage of Biochar

A study by Luca, Kenzie and Gundale, (2009) revealed that addition of biochar to the soil will increase soil microbial population and reduce soil bulk density. Biochar application helps to increase crops productivity and production yield through enhancing soil nutrient supply and microbial activity. It also helps in decreasing nutrient leaching (Hussain et al., 2016). A study by Ch'ng, Ahmed and Majid (2014) concluded that biochar is a carbonaceous substance that can be used for soil additive in agriculture in planting crops.

Average pH value of derived biochar from herbaceous biomass was 2 units higher than biochar that derived from woody biomass (Cai & Chang, 2016). Biochar from the spent coconut coir, wood chips and pulp sludge can be used as growth media for greenhouse. A study by Zhang, Tan, Wang, Ma and Welacky (2016) revealed that application of an organic amendments helps to improve water infiltration and enhance P transport deeper into soil profile. All the biochar that are used for growth media is suitable for hydroponic vegetable production (Khan et al., 2016). Besides, biochar derived from rice husk that undergo treatments with magnesium phosphate and lime will increase rood nodule formation, plant yield, and growth (Blackwell, Riethmuller & Collins, 2009).

Next, biochar also can be used for disease suppression. Biochar is free from any indigenous microbial populations but biochar also have large porous network that can potentially provide habitat to beneficial microorganism (Dong, Wu & Zhong, 2016) Moreover, biochar that is being treated with H_2PO_4 and potassium carbonate could act as a nutrient source due to slow release of impregnated potassium or phosphate from the biochar surface of treated biochar (Zhang, Voroney & Price, 2016). Next, biochar surface may adsorb bioavailable C, thereby reducing the immobilization of nitrate formed under biochar stimulation of nitrification (Luca, Kenzie & Gundale, 2009).

2.10 Mechanism of biochar in reducing phosphorus fixation

A study by Ch'ng, Ahmed and Majid (2014) concluded that the use of biochar and compost will reduce P fixation, because organic amendments have high affinity for Al and Fe which enable long term chelation of Al and Fe instead of P and P will be ready for crops uptake. A study by Faucon, Houben, Reynoird, Dulaurent, Armand and Lambers (2015) also proved that P concentration in soil will increase via application of biochar to acidic soils due to an increase in soil pH, which causes a decease of P sorption onto Fe and Al oxides. The pH value of the soil will increase by adding biochar to acid soils due to increased concentration of alkaline metal oxides that present in biochar and will reduce concentration of soluble soil Al^{3+} (Luca, Kenzie & Gundale, 2009).

When biochar is added to acidic soils, the soil pH will increase significantly along with the increase in the application rate of biochar. However, when pH value is more than 8, it become unsuitable for plants growth because it will affect availability of some elements (Cai & Chang, 2016). With biochar application, P concentration in the soil solution in non acidic soils will decease due to an increase in soil pH increase and large addition of cations such as Ca^{2+} and Mg^{2+} that will lead to P sorption and precipitation (Faucon, Houben, Reynoird, Dulaurent, Armand & Lambers, 2015). The application of biochar can increase the retention of P and the availability of P. It is due to the increase of cation exchange capacity (CEC) and decrease soluble Al in acidic soils (Prasad, Shivay, Majumdar & Prasad, 2016).

Biochar will retain nutrient in soil directly through negative charges that is developed on its surface and this negative charges can buffer acidic soils. When wood derived biochars are being applied to low fertility and acidic soil, leaching of P is significantly decreased (Major, Steiner, Downie & Lehman, 2009). Impact of biochar on P retention and release depend on soil pH. In additions, biochars will decrease the P sorption and will increase its availability in acidic soils. Biochar that has higher surface charge density helps to maintain cations for ion exchange, while existence both polar and nonpolar surface, high surface area and porosity helps biochar retain organic molecules and nutrients (Hussain et al., 2016).

Chapter 3

Methodology

3.1 Soil Sampling

Soil samples were collected from an undisturbed area in Agropark, Universiti Malaysia Kelantan Jeli Campus at 5°44’45.9’’N 101°52’01.31’’E. The soil sample was collected at 0 - 20 cm used auger.

Figure 3.1 : The location of Agropark UMK Jeli Campus

3.2 Initial Soil Samples Preparation and Analysis Before Incubation

The soil samples were air-dried for one week. After that, it was crushed manually using pestle and mortar. Then sieved to pass through 2 mm sieve.

3.2.1 Initial Characterization of Soil Sample

Before the incubation experiment was carried out, the soil samples was analyzed for pH and EC using pH meter and EC meter respectively (Peech, 1965). Soil texture was determined using the hydrometer method (Bouyoucos, 1965). Total organic matter and total C was determined using ashing method. Total P was extracted using Aqua Regia method (Bernas, 1968) whereas available P was extracted using Mehlich No. 1 Double Acid Method (Mehlich, 1953) afterwhich the molybdenum blue method (Murphy and Riley, 1962) was used to determined these forms of P in the extract. Potassium, Ca, Mg, Na, and Fe were determined using the Mehlich No. 1 Double Acid Method (Mehlich, 1953). Exchangeable acidity and Al were determined using the method described by Rowell (1994). The C:N and C:P ratios of the soil was calculated using the total C, N, and P value obtained. Details of the aforementioned procedures were described in Chapter 3, section 3.2.

3.2.1.1 Soil texture Determination

Soil texture was determined using the hydrometer method (Bouyoucos, 1962). A 50 g of soil sample was placed in a blender cup. The pH was adjusted to 10 by adding drop wise of 4 M NaOH. The blender cup was filled with distilled water to within 10 cm of the top rim. Afterwards, the blender cup was placed on the stirring machine and mixed for 15 minutes. At the end of 15 minutes, the soil suspension was transferred into a 1 L measuring cylinder. Distilled water was added to the measuring cylinder to make up a volume of 1,130 mL. The soil suspension was stirred for 40 seconds using a stirring rod. After stirring, a hydrometer was placed into the suspension and the meniscus on the hydrometer stem was recorded. Afterwards, the hydrometer was removed and rinsed. The soil suspension was stirred again and the second reading of the hydrometer was recorded. The result obtained was equivalent to the amount of slit and clay in grams of the soil sample. After that, the soil suspension was stirred again and third hydrometer reading and temperature readings was taken after 2 hours of settling time. The calculation for the soil texture is as follows :

Percentage of sand + silt + clay = 100%

40 seconds reading :

Percentage of silt + clay = (a/50)x 100% =w

Percentage of sand = (100 - w) = x

After 2 hour reading :

Percentage of clay = (b/50) x 100% = y

By difference : Percentage of silt = w - y = z

3.2.1.2 Soil pH and Electrical Conductivity Determination

The soil pH and electrical conductivity (EC) were determined using the potentiometric method with a ratio of 1:2.5 (soil : distilled water suspension) using a digital pH meter and EC meter (Peech, 1965). A 12.5 mL of distilled water was added to 5 g of air dried soil in a beaker at a ratio of 1:2.5. The samples was shaken for 15 minutes at 180 rpm. Afterwards, the samples will be left to stand overnight for 24 hours before using a pH meter for pH determination and EC meter for EC determination.

3.2.1.3 Soil Organic Matter and Soil Total Carbon Determination

The soil organic matter was determined using loss of ignition method (Tan, 2003). The mass of an empty and dry crucible was weighed and recorded. Then, oven dried test sample was placed in the porcelain dish and the mass of the crucible and soil specimen (M_{PDS}) was determined and record. Next, the crucible was placed in a muffle furnace. The temperature in the furnace was gradually increase to 440 °C and the specimen was left overnight. Then, the crucible was carefully brought out by using tong and allowed it to cool to the room temperature in a dessicator. The mass of the crucible containing the ash was determine and recorded, (M_{PA}). Then, the dish was emptied and cleaned. The percentage of organic matter content was calculated using the following equation:

Organic matter content (%) = [Organic matter mass, (M_o) / Mass of soil, (M_D)] x 100

Where , M_D = Mass of oven dried soil (M_{PDS} - M_P)

M_A = Mass of ash (burned) soil (M_{PA} - M_P)

M_O = Mass of organic matter (M_D - M_A)

The percentage of soil total carbon was determined by the formula described by Tan (2003) :

Soil Organic Matter = Z x 0.58

Where Z = Total C (%)

3.2.1.4 Soil Available Phosphorus Determination

The soil available P was extracted using Mehlich No. 1 Double Acid Method (Mehlich, 1953). Firstly, 4 mL of concentrated HCL and 0.7 mL concentrated H_2SO_4 were pipetted into a 1000 mL volumetric flask and the volume was made up to volume. A 10 g of soil sample was weighed and placed into a 50 mL conical flask. After that, a 40 mL of the extraction reagent was added and the solution was shaken for 10 minutes on a reciprocal shaker. Afterwards, the supernatant was filtered into beaker using Whatman Filter paper No. 2, and the extract of P was collected. The solution was analyzed by the molybdenum blue method (Murphy and Riley, 1962). The developed blue colour was analyzed by UV-VIS spectrometer at 882 nm wavelength. The soil available P remain was calculated using the equation shown below :

Soil available P (ppm) = UV- VIS reading (ppm) x [Volume of extractant (mL) / Weight of soil (g)] x [Volume of volumetric flask (mL) / Volume of sample added to develop blue colour (mL)]

3.2.1.5 Soil Exchange Cation Determination

The soil exchangeable cation (K, Ca, Mg, Na, Fe, Cu, and Zn) was extracted using Mechlich No. 1 Double Acid Method (Mehlich, 1953). A 5 g of soil sample was weighed and placed into a 50 mL extraction vessel. After that, a 25 mL of the extraction reagent was added and the solution was shaken for 10 minutes on a reciprocal shaker. Afterwards, the supernatant was filtered into beaker using Whatman Filter Paper No. 2, and the extract was collected. An Atomic Absorption Spectrophotometer (AAS) (Pin AAcle 900F, USA) was calibrated and the extract was aspirated into the AAS and the absorbance reading was recorded.

The soil exchangeable cations was calculated using the equation shown below :

Soil exchangeable cation (ppm) = AAS reading (ppm) x [Volume of extractant (mL) / Weight of the soil sample (g)]

3.2.1.6 Soil Exchangeable Acidity and Exchangeable Aluminum Determination

Soil exchangeable acidity and Al were determined using titration mehod described by Rowell (1994). A 10 g of soil and 30 mL of 1 M potassium chloride (KCL) was placed in a beaker and left overnight (24 hours). The sample was filtered with Whatman paper No.2 into a 100 mL volumetric flask after 24 hours and volume was made up to the mark. After that, 50 mL of the soil extract was pipetted into a 250 mL conical flask. Five drops of phenolphthalein indicator was added. The solution was titrated against 0.01 M NaOH until the appearance of pink colour. This measured the soil exchangeable acidity. The solution was then titrated with 0.01 M HCl until the solution become colourless and this measured the soil exchangeable Al. The calculation will be outlined as follow :

Exchangeable acidity (cmol kg^{-1}) = [0.2 x Titrate volume of 0.01 M NaOH x 10] / soil mass (g)

Exchangeable Al cmol kg^{-1}) = [0.2 x Titrate volume of 0.01 M HCl x 10] / soil mass (g)

3.3 Incubation study

An incubation study was carried out for 90 days at Universiti Malaysia Kelantan Jeli Campus, Malaysia. From the bulked 2 mm soil sample, 300 g of the soil was weighed using a digital balance for each treatment into 8.5 cm x 5.5 cm plastic container. Each treatment was replicated three times. To understand the selected soil chemical properties particularly P availability after the application of rice straw biochar, only P fertilizers Egypt Rock Phosphate (ERP) (100% P_2O_5) was used in this incubation study, that is, N and K fertilizers was excluded in this incubation study. The rice straw biochar was produce from the pilot carbonator at temperature of 300 - 350 °C located in Institute of Advanced Technology (ITMA), University Putra Malaysia (UPM). The rates of the P fertilizers ERP used in this incubation study were 60 kg P_2O_5 ha^{-1}. This rates was based on the standard recommendation for maize (Zea mays L.) cultivation (MARDI, 1993). Based on these recommendation, 5 g of ERP per 500 mL beaker and 28.8 g of biochar per 500 mL beaker will be used. The rate of P fertilizers, ERP and biochar was scaled down to per container basis from the standard recommendation rates as described previously. The soil ERP,and biochar was thoroughly mixed. The container with the treatments was sealed with parafilm. The parafilm was perforated to ensure good aeration.

Information about the treatments evaluated in this laboratory incubation study is summarized as follows :

Table 3.1 : List of treatments in incubation study.

Treatments		Description
T0	:	Soil only
T1	:	Soil + 100% ERP
T2	:	Soil + 75% ERP
T3	:	Soil + 50% ERP
T4	:	Soil + 25% ERP
T5	:	Soil + 100% ERP + 20 t ha^{-1} Biochar
T6	:	Soil + 75% ERP + 20 t ha^{-1} Biochar
T7	:	Soil + 50% ERP + 20 t ha^{-1} Biochar
T8	:	Soil + 25% ERP + 20 t ha^{-1} Biochar
T9	:	Soil + 20 t ha^{-1} Biochar only

The treatments was arranged in a factorial in completely randomized design. The samples was incubated for 30 days, 60 days and 90 days, respectively. Each treatment had three replications (that is 30 samples for 30 days of incubation, 30 samples for 60 days of incubation, 30 samples for 90 days of incubation). The soil samples was maintained at water holding capacity throughout the incubation process. The temperature of the experimental room was maintained at 27°C. At 30 days, 60 days and 90 days of incubation (DAI), the soil samples was air dried and analyzed for pH, available P, exchangeable acidity, exchangeable Al, Ca and Fe. Details of the aforementioned procedures can be found in Chapter 3, section 3.2.

Figure 3.2 : Layout of laboratory incubation study.

3.4 Statistical Analysis

Analysis of variance (ANOVA) was used treatment effect whereas Duncan HSD test was used to compare treatment means at P≤0.05. The IBM SPSS Statistics 21 was used for the aforementioned statistical analysis.

Chapter 4

Result and Discussion

4.1 Selected Physico-chemical Properties of Soil Sample

Table 4.1 shows the selected physico-chemical properties of the soil sample. The soil texture was a sandy clay loam with low pH value of 5.31 and EC value of 7 . The total sol organic matter was 10.87%. The exchangeable K, Ca, Mg, Na, Fe, Cu and Zn were 24.148, 69.92, 0.484, 14.888, 56.84, 0.208, and 0.484 ppm, respectively. The available P in the soil was low due to low soil pH and acidic soil. Moreover, the high value of exchangeable Al and exchangeable Fe contributes to the low of available P in the soil.

Table 4.1 : Selected physico-chemical properties of soil.

Property	Value Obtained
Soil Texture	Sand : 75% Clay : 24% Slits : 1% Sandy Clay Loam
pH	5.31
EC	7
Soil Organic Matter (%)	10.87
Soil Total Carbon (%)	6.31
Available P (ppm)	1.258
Exchangeable K (ppm)	24.148
Exchangeable Ca (ppm)	69.92
Exchangeable Mg (ppm)	0.484
Exchangeable Na (ppm)	14.888
Exchangeable Fe (ppm)	56.84

Exchangeable Cu (ppm)	0.208
Exchangeable Zn (ppm)	0.484
Exchangeable Al (cmol kg^{-1})	0.320
Exchangeable Acidity (cmol kg^{-1})	0.567

4.2 Selected Physico-chemical Properties of Rice Straw Biochar

Table 4.2 shows the selected physico-chemical properties of the rice straw biochar. The rice straw biochar had pH value of 9.5 and EC value of 5.2 dS/m. The total C was 29.34%. The available P in the rice straw biochar was 0.21 ppm and total nitrogen was 0.50%. The exchangeable K, Ca, Mn, Fe and Zn were 794.1, 4653.3, 299.4, 655.1 and 60.6 mg kg^{-1}, respectively.

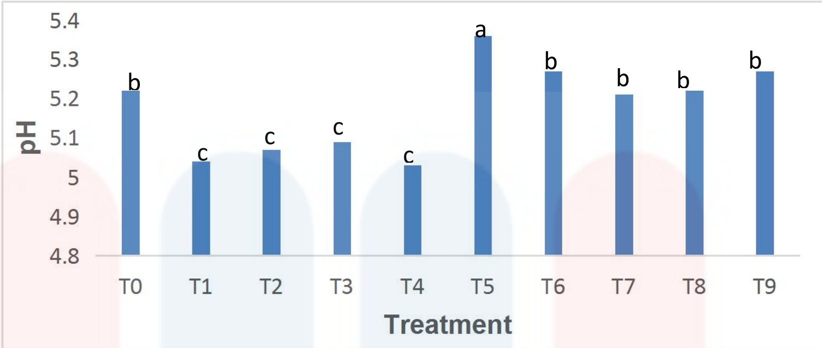
Table 4.2 : Selected physico-chemical properties of rice straw biochar.

Property	Value Obtained
pH	9.5
EC (dS/m)	5.2
Total Carbon (%)	29.34
Available P (ppm)	0.21
Total Nitrogen (%)	0.50
Exchangeable K (mg kg^{-1})	794.1
Exchangeable Ca (mg kg^{-1})	4653.3
Exchangeable Mn (mg kg^{-1})	299.4
Exchangeable Fe (mg kg^{-1})	655.1
Exchangeable Zn (mg kg^{-1})	60.6

4.3 Soil pH

From the Figure 4.1, the soil pH of treatments with mixture of rice straw biochar (T5, T6, T7, T8, T9) were significantly increased compared with treatment without rice straw biochar (T0, T1, T2, T3, T4). The soil pH at 30 days, 60 days and 90 days also increased progressively in the treatment with mixture of rice straw biochar.

The increased in soil pH was due to the pH of the rice straw biochar of 9.6 that is alkaline (Table 4.2). Besides, the rice straw biochar has negative charge that developed on its surface and these negative charges will bind with Al^{+} and Fe^{+} then buffer acidic soils. The increase of soil pH was due to the exchange of H^{+} ions between soil and the organic amendments (Ch'ng, Ahmed & Majid, 2014). According to Mukome and Parikh (2016), biochar were usually used to increased the pH of the acidic soils that affects the mobility of cations in the soils.



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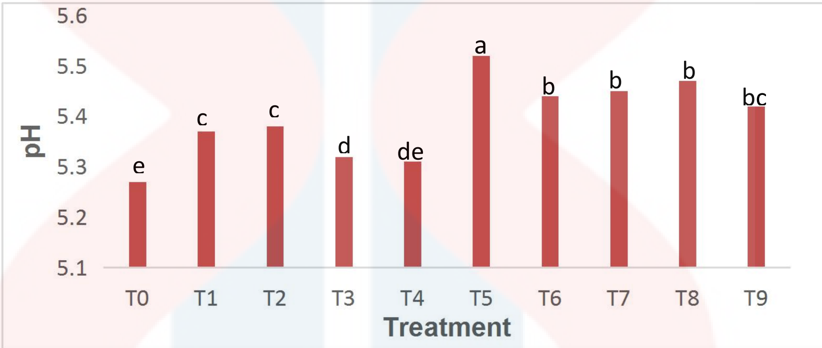

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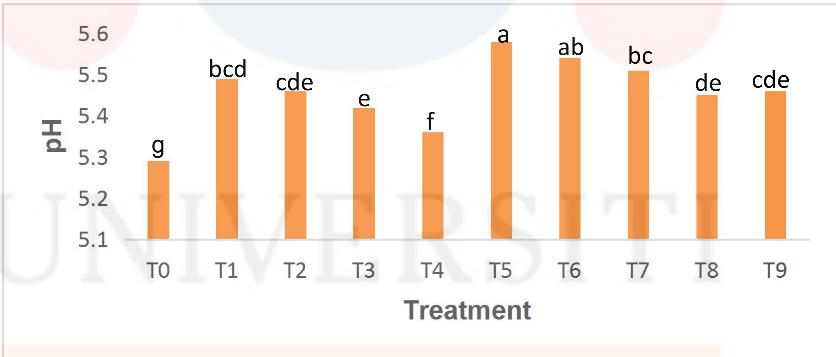

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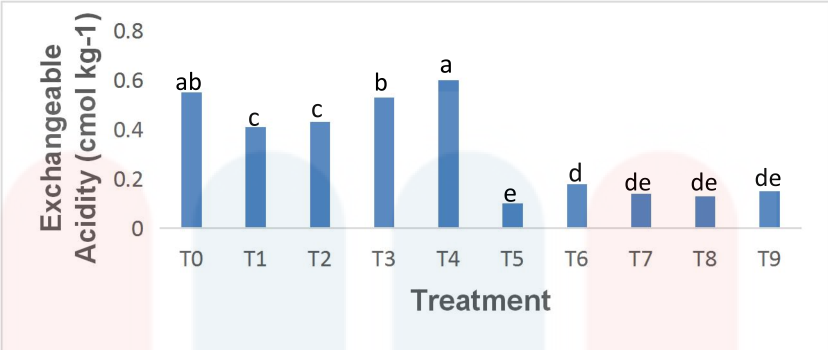
Figure 4.1 : Effect of treatments on soil pH at (a) 30 days after incubation, (b) 60 days after incubation, (c) 90 days after incubation. Means between columns with different letter(s) indicates significant difference between means by Duncan's test at p≤0.05.

4.4 Soil Exchangeable Acidity and Exchangeable Aluminum

The exchangeable acidity in treatments that contain rice straw biochar (T5, T6, T7, T8, T9) decreased significantly compared to treatment without rice straw biochar (T0, T1, T2, T3, T4) (Figure 4.2). By adding rice straw biochar in the treatment, it reduced the soil acidity and also the soil pH. This statement is proven by several studies suggesting that biochar are mostly alkaline and were used in the acidic soils to reduce the acidity that affects the mobility of cations in the soils (Mukome & Parikh., 2016 ; Ch'ng, Ahmed & Majid, 2014). Biochar has negative charge developed on its surface and the negative charges can buffer the acidic soils.

Treatments that contain rice straw biochar (T5, T6 T7, T8, T9) had significantly lower exchangeable Al compared to treatment that did not contain rice straw biochar (T0, T1, T2, T3, T4) (Figure 4.3). The higher exchangeable Al in T0, T1, T2, T3 and T4 can be related with soil pH value (Figure 4.1). As the soil is acidic, the total exchangeable Al in the soil increases. The soil texture of this soil is sandy clay loam. The presence Al ions in clay will make the soil become acidic. After adding rice straw biochar, the exchangeable Al decreased significantly. It was due to negative charges that developed on its surface that will bind with the positive charges of Al. The opposite attraction will occur and the exchangeable of Al will decreased (Prasad, Shivay, Majumdar & Prasad, 2016). The treatments that contain fertilizer (T1,T2, T3, T4) and soil only (T0) had high exchangeable of Al concentration was due to presence of clay that contain high number of Al ions. The reduction in exchangeable acidity and Al relates to the soil pH (Figure 4.1). The increase in pH results in the precipitation of exchangeable of soluble Al as insoluble Al hydroxides, thus reducing the concentration of Al in the soil solution. The complex formation with low molecular weight organic acid and humic substances produced during the decomposition of biochar also explain the significant reduction of exchangeable Al in the soil solution (Ch'ng, Ahmed, Majid & Jalloh, 2016).



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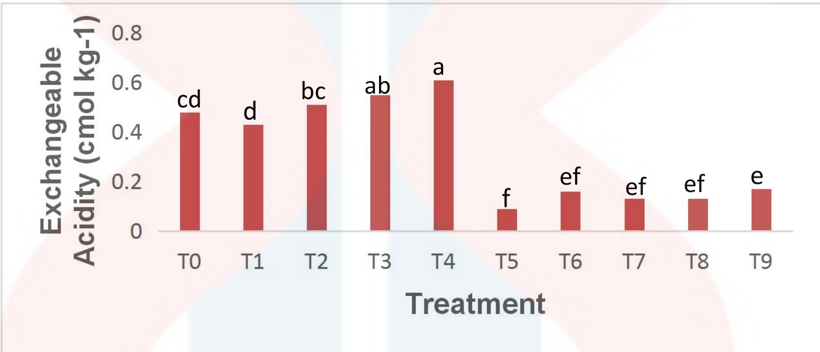

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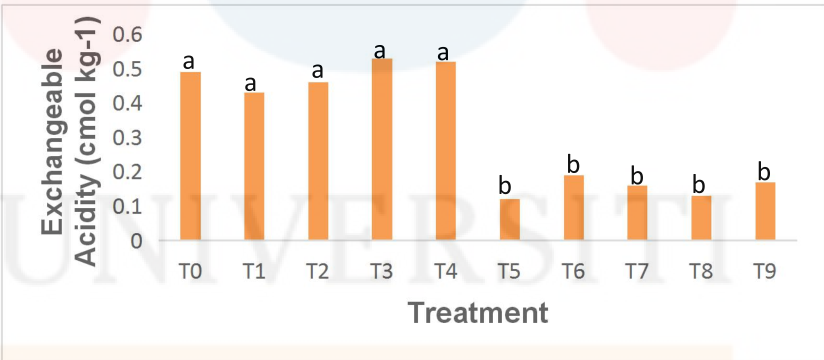

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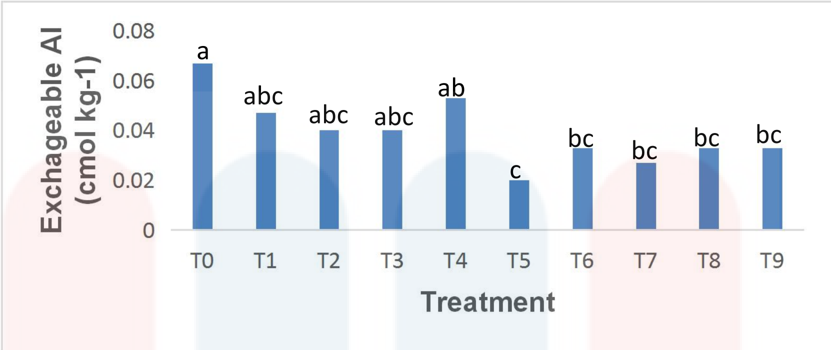
Figure 4.2 : Effect of treatments on exchangeable acidity at (a) 30 days after incubation, (b) 60 days after incubation, (c) 90 days after incubation. Means between columns with different letter(s) indicates significant difference between means by Duncan's test at $p \leq 0.05$.



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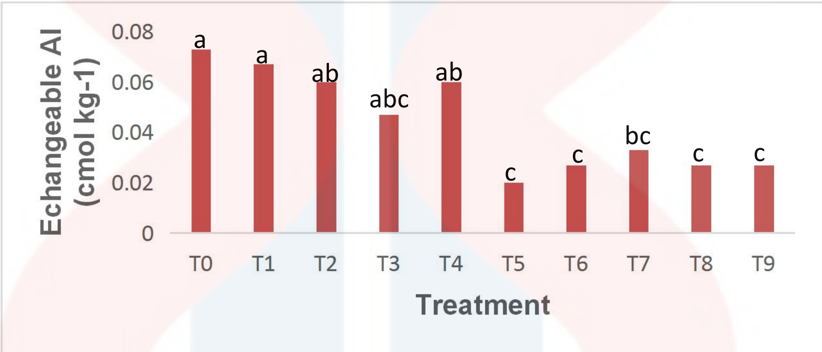

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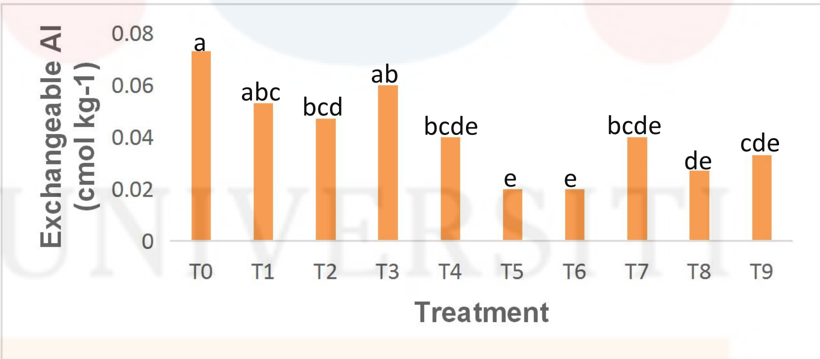

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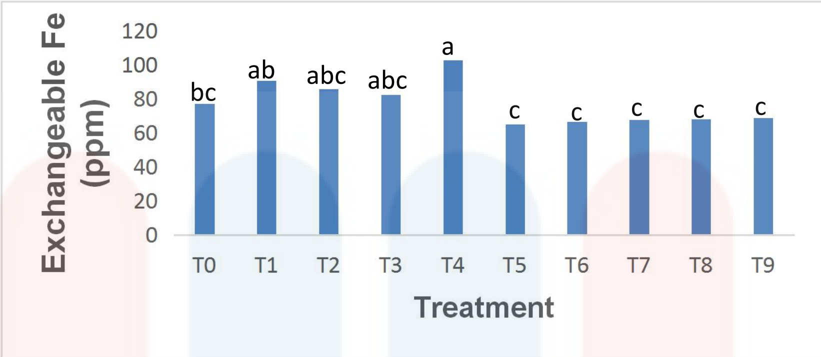
Figure 4.3 : Effect of treatments on exchangeable Al at (a) 30 days after incubation, (b) 60 days after incubation, (c) 90 days after incubation. Means between columns with different letter(s) indicates significant difference between means by Duncan's test at p≤0.05.

4.5 Soil Exchangeable Iron

The Figure 4.4 shows that the treatment without rice straw biochar (T0, T1, T2, T3, T4) had significantly higher exchangeable Fe in the soil compared to treatment with rice straw biochar (T5, T6, T7, T8, T9). The exchangeable Fe changes between 30 days, 60 days and 90 days was decreased for the soil treatment with rice straw biochar.

The biochar is to fix the Fe to prevent it from binding with P (Ch'ng, Ahmed & Majid, 2014). Biochar has negative charges developed on its surface to fix with Fe. Besides, this was also due to the liming effect of the ERP which in turn raised the soil pH (Figure 4.1) and have reduced the concentration of the exchangeable Fe.



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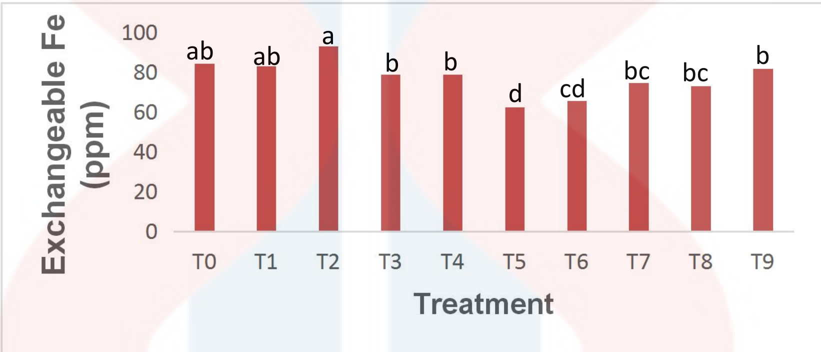

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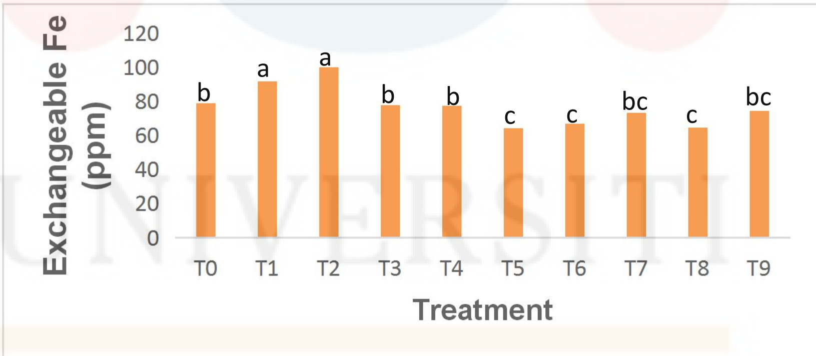

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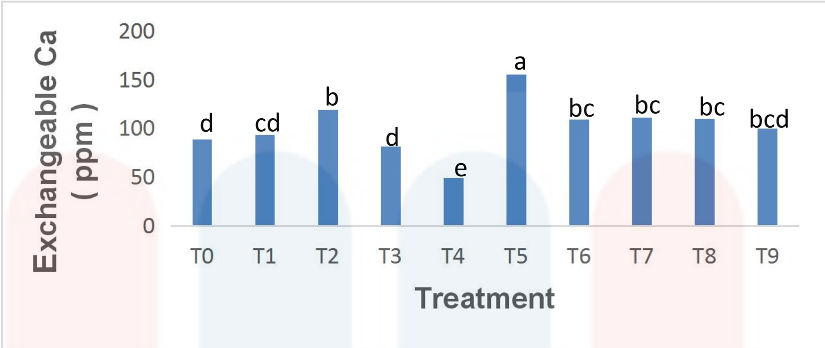
Figure 4.4 : Effect of treatments on exchangeable Fe at (a) 30 days after incubation, (b) 60 days after incubation, (c) 90 days after incubation. Means between columns with different letter(s) indicates significant difference between means by Duncan's test at $p \leq 0.05$.

4.6 Soil Exchangeable Calcium

Figure 4.5 shows that the treatment with rice straw biochar (T5, T6, T7, T8, T9) increased the exchangeable Ca significantly compared to treatments without rice straw biochar (T0, T1, T2, T3, T4) in the soil. The exchangeable Ca changes between 30 days, 60 days and 90 days was increased for the soil treatment with rice straw biochar. Biochar has relatively high Ca content (Ch’ng, Ahmed & Majid, 2014). Furthermore, the selected physico-chemical for rice straw biochar in this study had higher content of Ca, (4653.3 mg kg^{-1}) (Table 4.2). Besides, the chemical fertilizer, ERP has relatively high concentration of Ca also the Ca retention in the soil (Ch’ng, Ahmed, Majid & Jalloh, 2016).



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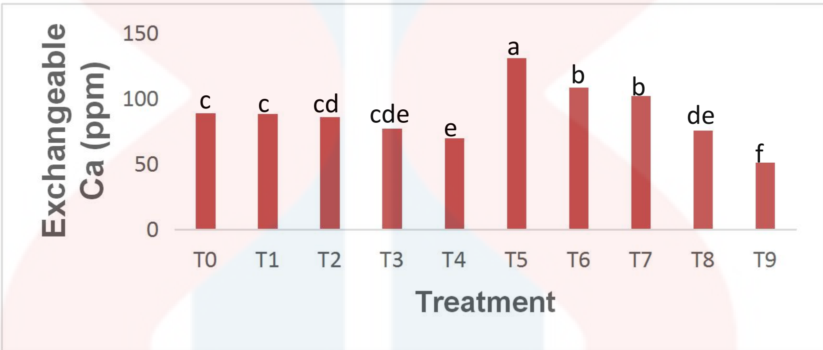

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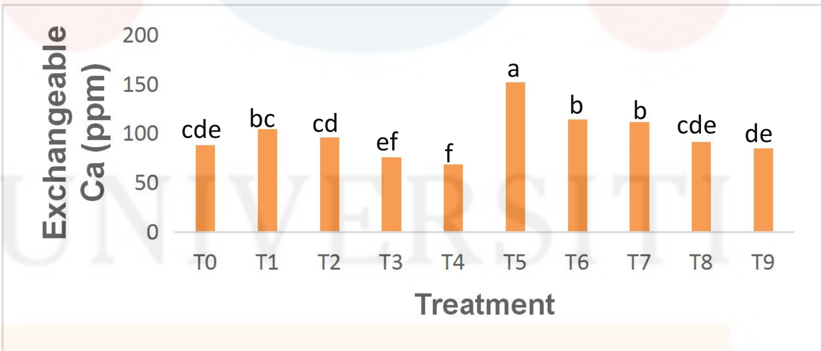

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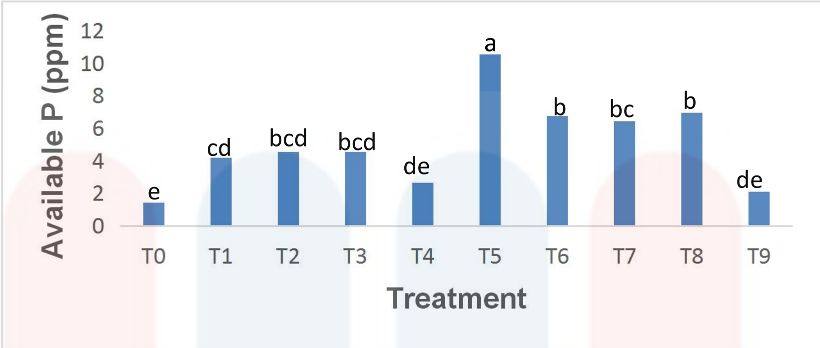
Figure 4.5 : Effect of treatments on exchangeable Ca at (a) 30 days after incubation, (b) 60 days after incubation, (c) 90 days after incubation. Means between columns with different letter(s) indicates significant difference between means by Duncan's test at $p \leq 0.05$.

4.7 Soil Available Phosphorus

Figure 4.6 shows treatments contained rice straw biochar (T5, T6, T7, T8, T9) increased soil available P significantly compared to soil treatment that contain chemical fertilizer (T1, T2, T3, T4) and soil only (T0). The application of biochar increased the P retention and P availability due to increases CEC and decreased soluble Al ad Fe in acidic soils (Prasad, Shivay, Majumdar & Prasad, 2016) (Figure 4.2 and Figure 4.3).

According to Ch'ng, Ahmed, Majid and Jalloh (2016) state the use of biochar will help in reduced the P fixation, because organic amendments have high affinity for Al and Fe which enable long term chelation of Al and Fe instead of P and P will be ready for crops uptake. Besides that, in acidic soil, P availability were low due to low pH value. By adding biochar, it will increase the soil pH together with P availability. According to Faucon, Houben, Reynoird, Dulaurent, Armand and Lambers (2015) the application of biochar increased the soil pH and P concentration (Figure 4.1 and Figure 4.6).



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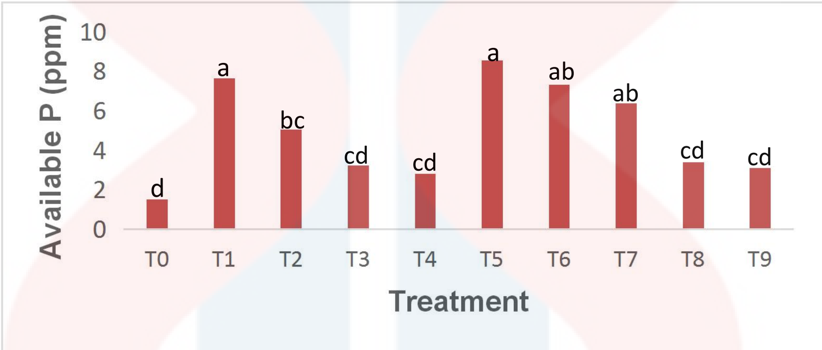

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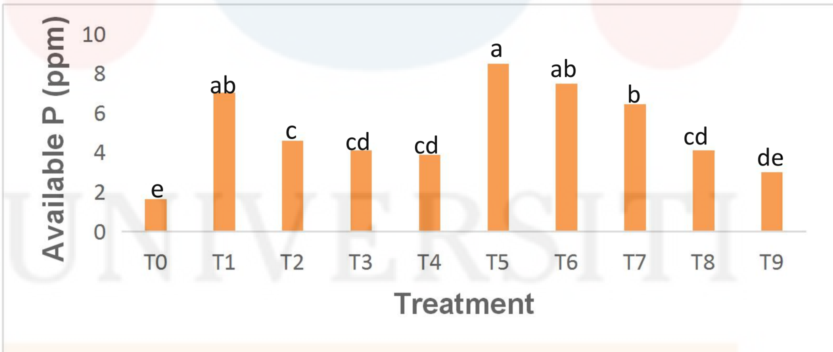

(c)

Figure 4.6 : Effect of treatments on soil available P at (a) 30 days after incubation, (b) 60 days after incubation, (c) 90 days after incubation. Means between columns with different letter(s) indicates significant difference between means by Duncan’s test at p≤0.05.

Chapter 5

Conclusion and Recommendation

The biochar that derived from rice straw can be used to improve the P availability in the soil by reducing the P fixation. Treatments added with rice straw biochar significantly increased the soil pH, increase exchangeable ca, reduced the exchangeable Al, exchangeable Fe and exchangeable acidity in the soil. Furthermore, the treatment of rice straw biochar with chemical fertilizer can increase the total available P compared to treatment of soil with chemical fertilizer with soil only. As recommendation, this study can be further evaluated with other type of biochar to analyze its potential towards the available P in the soil.

References

Antoniadis, V., Koliniati, R., Efstratiou, E., Golia, E., & Petropouls, S. (2016). Effect of Soil with Varrying Degree of Weathering and pH Value on Phosphorus Sorption. *Catena 139 (2016)214-219.*

Amin, F. R., Huang, Y., He, Y., Zhang, R., Liu, G., & Chen, C. (2016) Biochar Application and Modern Techniques for Characterization. 18:1457-1473

Arai, Y., & Livi, K. J. (2012). Underassed Phosphorus Fixation Mechanism in Soil Sand Fraction. Geoderma 192(2013)422-429.

Blackwell, P., Riethmuller, G., & Collins, M. (2009). Biochar Application to Soil. In : J. Lehmann, & S. Joseph, *Biochar for Environmental Management Science and Technology* (pp. 207-214). Earthscan, USA

Boundless, "The Phosphorus Cycle." Boundless Microbiology, 26 May. 2016. Retrieved 21 Jan 2017 from https://www.boundless.com/microbiology/textbooks/boundless-microbiolofy-textbook/microbial-ecology-16/nutrients-cycle-195/the-phosphorus-cycle-983-459/

Bouyoucos, G.j. (1962). Hydrometer improved for making particle size analysis of soils. *Agronomy Journal 54:464-465*

Bremner, J.M. & Lees, H. (1949). Studies on Soil Organic Matter Part II : The Extraction of Organic Matter From Soil By Neutral Reagents. *Journal of Agricultural Science 39:274-279*

Busman, L., Lamb, J., Randall, G., Rehm, G., & Schmitt, M. (2002). The Nature of Phosphorus in Soils. Retrieved 25 January, 2017 from University of Minnesota website : http://www.extension.umn.edu/agriculture/nutrient-management/phosphorus/the-nature-of-phosphorus/

Cai, Y., & Chang, S. X. (2016). Biochar Effect On Soil Fertility And Nutrient Cycling. In: Y. S.O. , S. M. Uchimiya, S. X. Chang. *Biochar* (pp. 167-220). Florida: Taylor and Francis Group.

Ch'ing, H. Y., Ahmad, O. H., & Majid, N. M. (2014). Improving Phosphorus Availability In An Acid Soil Using Organic Amendments Produced From Agroindustrial Waste. *The Scientific World Journal. V-2014*,6

http://dx.doi.org/10.1155/2014/506356

Ch'ing, H. Y., Ahmad, O. H., Majid, N. M. & Jalloh, M. B. (2016). Reducing Soil Phosphorus Fixation to Improve Yield of Maize on a Tropical Acid Soil Using Compost and Biochar Derived from Agro-Industrial Waste, Compost Science & Utilization.

Daily Express. (2015). Attention to rice sufficient. Retrieved March,17,2017 from the Independent National Newspaper Of East Malaysia.

http://dailyexpress.com.my

Luca, T. H., Kenzie, M. D. M., & Gundale, M. F. (2009). Biochar Effect on Soil Nutrient Transformation in Biochar Environmental Management In : J. Lehmann, S. Joseph. *Biochar for Environmental Management Science and Technology* (pp. 227-243) Earthscan, USA

Dong, D., Wu, W., & Zhong, T. (2016). Effects of s\Straw Derived Biochar on Rice Paddy.In: Y. S.Ok. , S. M. Uchimiya, S. X. Chang. *Biochar* (pp. 293). Florida: Taylor and Francis Group.

Dorbermain, A., & Fairhust, T. H. (2002). Rice Straw Management, Better Crops International, vol 16

Faucon, M. F., Houben, D., Reynoird, J. P., Dulaurent, A. M. M., Armand, R., & Lambers, H.(2015). Advance and PrespectIve to Improve The Phosphorus Availability Incropping System For Agroecological Phosphorus Management. Advance in Agronomy, 134

Filippelli, G. M., (2016). The Global Phosphorus Cycle. In: Rattan Lal, B. A. Stewart. *Soil phosphorus* (pp. 1-17). Florida: Taylor and Francis Group.

Grant, C. A., Flaten, D. N., Tomasiewicz, D. J., & Sheppard, S. C. (2000). The Importance of Early Season Phosphorus Nutrition. *Canadian Journal Plant Science. 2001.81*:211-224.

Hussain, M., Farooq, M., Nawaz, A., M. Al Sadi, A., Solaiman, Z. M., Alghamdi, S. S., Ammara, U., Y. S. Ok, & K. H.M. Soddique, (2016).Biochar for crop production : Potential Benefits and Risk. *Journal soil sediments*

Karim, R. S. M., Man, A., & Sahid, I. (2004). Weed Problem and Their Management in Rice Fields of Malaysia : An Overview. In Weed Biology and Management 4, 177-186 (2004)

Khan, A., Savidov, N., Zhang, J., Yang, J., Anderson, T., Harfield, D., & Anyia, A. O. (2016). Biochar substrate for hydrophonic vegetable production. In: Yong S.O. , S. M. Uchimiya, S. X. Chang. *Biochar* (pp. 273-292). Florida: Taylor and Francis Group.

Kruse, J., Abraham, M., Amelung, W., Baum, C., Bol, R., Ku¨hn, O., Lewandowski, H., Niederberger, J., Oelmann, Y., Ruger, C., Santner, J., Siebers, M., Siebers, N., Spohn, M., Vestergren, J., Vogts, A., & Leinweber, P. (2015). Innovative Methods In Soil Phosphorus Resarch : A Review. *Journal Plant Nutrition Soil Science. 2015, 178, 43-88*

Kunhikrishnan, A., Bibi, I., Bolan, N., Seshadri, B., Choppala, G., Nianzi, N. K., Kim, W., & Ok. Y. S. (2016) Biochar for Inorganic Contaminant Management in Waste and Wastewater. In: Y. S.Ok. , S. M. Uchimiya, S. X. Chang. *Biochar* (pp. 167-220). Florida: Taylor and Francis Group.

Kunhikrishnan, A., Thangarajan, R., Bolan, N., Mandal, S., Choppala, G., Karunanithi, R., & Qi, F. (2016) Biochar for Inorganic Contaminant Management in Soil. In: Y. S.Ok. , S. M. Uchimiya, S. X. Chang. *Biochar* (pp. 99-138). Florida: Taylor and Francis Group.

Margenot, J, A., Singh, B. R., I. M., & Sommer, R. (2016). Phosphorus Fertilization and Management in Soils of Sub-Saharan Africa. In: R. Lal, B. A. Stewart. *Soil phosphorus* (pp. 152-190). Florida: Taylor and Francis Group

Marguire, R. O. (2014). Importance of farm phosphorus mass balance and management options. *Virgia Cooperative Extension.*

Major, J., Steiner, C., Downie, A., & Lehmann J. (2009). Biochar Effects on Nutrient Leaching. In : J. Lehmann, S.Joseph. *Biochar for Environmental Management Science and Technology* (pp. 271-289). Earthscan, USA

Marjenah, Kiswanto, Purnawati, S., & Sofyan, F. P. M. (2016). The Effect of Biochar, Cocopeat and Saw Dust Compost on The Gowth of Two Dipterocraps. *Nusantara Bioscience, vol 8, no1 pp 39-44*

Mehlich, A. (1953). *Determination of P, Ca, Mg, K, Na anh NH4*. Releigh, NC: North Carolina State University Soil Test Division.

Murphy, J and Jl. Riley (1962). A modified single solution method for the determination of phosphate in natural waters. Analytical Chimica Act 27 :31-36

Mukome, F. N.D., & Parikh, S. J. (2016) Biochar Production and Characterization. In: Y. S.Ok. , S. M. Uchimiya, S. X. Chang. *Biochar* (pp. 67-98). Florida: Taylor and Francis Group.

Peech, H.M. (1965). Hydrogen ion activity, In: Method of soil analysis, Part 2, C.A. Black, D.D. Evans, L.E.Ensminger, J.L. White. F.E. Clark,. R.c. Dinauer (eds). Madison, WI : American Society of Agronomy

Prasad, R., Lal, R., & Prasad, S. (2016). Phosphorus in Soil and Plants in Relation to Human Nutrition and Health. In: R. Lal, B. A. Stewart. *Soil phosphorus* (pp. 65-74). Florida: Taylor and Francis Group.

Prasad, R., Shivay, Y. S., Majumdar, K., & Prasad, S. (2016). Phosphorus Management. In: R. Lal, B. A. Stewart. *Soil phosphorus* (pp. 82-102). Florida: Taylor and Francis Group.

Roberts, T. L., & Johnston, A. E. (2015). Phosphorus Use Efficiency & Management in Agriculture. *Resources, Conservation and Recycling 105(2015)275-281*

Rowel, D.L. (1994) soil science : Method and application, England: prentice Hall

Tan. K. (2003). Soil Sampling, Preparation and Analysis. New York: Taylor & Francis Inc.

Turner, B. L., & Blackwell, M. S. A. (2013). Isolating The Influence of pH on The Amount and Forms of Soil Organic Phosphorus. *European Journal of Soil Science. 64,*245-259

Uchimiya, S. M. (2016) Biochar Production Technology. In: Y. S.O. , S. M. Uchimiya, S. X. Chang. *Biochar* (pp. 45-65). Florida: Taylor and Francis Group.

Doi:10.1111/ejss.12026

Yuksek, T., Kurdoglu, O., & Yuksek, F. (2010). The Effects Of Land Use Changes and Management Types on Surface Soil Properties in Kafkasor Protected are in Artivin, Turker. *Land Degradation & Development 21*:582-590

Doi:10.1002/ldr.1000

Zhang, H., Voroney, R. P., & Price, G. W. (2016). Biochar effects on soil organic carbon storage. In: Yong S.O. , S. M. Uchimiya., & S. X. Chang. *Biochar* . Florida: Taylor and Francis Group.

Zhang, T. Q., Tan, C. S., Wang, Y. T., Ma, B. L., & Welacky, T. (2016). Soil Phosphorus Loss In Tile Drainage Water From Long Term Conventional and Non Tillage Soils of Ontario With and Without Compost Addition. *Science of The Total Environment 580, 9-16*