Assessment of Soil Phosphorus Sorption and Desorption Characteristic of Tropical Acid Soil Amended With Rice Straw Compost

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

Faculty of Agro-based Industry

UNIVERSITI MALAYSIA KELANTAN

2019

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 certify that the report of this final year project entitled "Assessment of Soil Phosphorus Sorption and Desorption Characteristic of Tropical Acid Soil Amended With Rice Straw Compost" by NUR NAZIHAH ABDUL GHAFFAR, matric number F15A0156 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, Universiti Malaysia Kelantan.

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ACKNOWLEDGEMENT

First, all praises to Almighty Allah for the blessing and mercy that given me to complete my research project.

I would like to acknowledgement with deep appreciation and gratitude to the invaluable help of my supervisor, Dr Ch'ng Huck Ywih. He had given his valuable guidance, advices, suggestions and expertise patiently in guiding me throughout my final year project as well as my thesis writing. He had also keep support me to complete my project work as soon as possible.

Next, I would like to thank the staff of University Malaysia Kelantan who are takes parts give me some guidance throughout the completion of my final year project. I would to deliver my sincere thanks to laboratory assistants, Mr. Nik Fakruddin, Mr. Qamarul, and Mrs. Nur Hidayah for their patiently guidance, support and giving me permission to allow me use the laboratory facilities. There, I could carry out the process of this project smoothly.

I also wish to thank my family and friends for their inspiration. My parent always gives their support and encouragement during research. Thanks also to my friends that helped me by accompanying and help finalizing this project within the limited time frame. Once again, special thanks and appreciation to Syajariah Sanusi, Dr Huck's master student for her willingness to help me and my friends complete our research project.

Nur Nazihah Binti Abdul Ghaffar, January 2019.

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ABSTRACT

Phosphorus is an essential crop macronutrient because of the relatively large amount of P required by plants. Application of organic amendment is highly recommended to minimize the phosphorus sorption in the acidic soils. The research examined changes in phosphorus sorption and desorption and compost pH buffering capacity. Thus, the objective of this study are to determine the changes in the soil phosphorus sorption and desorption upon application of rice straw compost and to determine the soil phosphorus maximum buffering capacity that is resistant to change in phosphorus concentration of the soil of the labile solid phase. Rice straw compost was used and the sorption data were fitted to Langmuir equation. The result showed phosphorus sorbed was decreased as the phosphorus concentration increased whereas phosphorus desorption increase significantly with increasing the phosphorus application rates (10 to 30 mg L^{-1}). The sorption of phosphorus increase due to increase in soil organic matter which are highly negatively charged thus cause the precipitation of exchangeable aluminium and iron in soil. Besides, high pH buffering capacity of compost was reported in this study. This was due to increase cation exchangeable capacity thus can help in increasing the pH of acidic soil. Amendment of rice straw compost with soil can repay for phosphorus losses in soil through leaching of tropical acid soil by increase phosphorus availability and reduced phosphorus fixation.

Keywords: Phosphorus, rice straw compost, sorption, desorption, pH buffering capacity

Penilaian Ciri Tanah Bagi Penyerapan dan Desorpsi Fosforus Pada Tanah Asid Tropika Dengan Menggunakan Kompos Jerami

ABSTRAK

Fosforus adalah makronutrisi tanaman yang penting kerana diperlukan oleh tumbuhan dalam kuantiti yang banyak. Penggunaan bahan organik sangat digalakkan untuk meminimumkan penyerapan fosforus dalam tanah berasid. Kajian ini mengkaji perubahan dalam penyerapan dan desorpsi fosforus dan kapasiti kompos pH bufer. Oleh itu, objektif kajian ini adalah untuk menentukan perubahan dalam penyerapan dan desorpsi fosforus tanah pada penggunaan kompos jerami dan untuk menentukan kapasiti penyerapan fosforus yang maksimum ke dalam tanah yang tahan terhadap perubahan dalam kepekatan fosforus tanah fasa pepejal labil. Kompos jerami digunakan dan data penyerapan dikira menggunakan persamaan Langmuir. Data penyerapan fosforus menurun apabila kepekatan fosforus meningkat manakala desorpsi fosforus meningkat dengan ketara apabila kadar penggunaan fosforus (10 hingga 30 mg L^{-1}) turut meningkat. Penyerapan fosforus meningkat disebabkan bahan organik tanah yang banyak , mempunyai permukaan negatif yang banyak sehingga terbentuk pemendakan penukaran aluminium dan besi di dalam tanah. Selain itu, kapasiti bufer pH yang tinggi direkodkan di dalam kajian ini. Hal ini disebabkan oleh pertukaran kapasiti yang meningkat dapat membantu meningkatkan pH tanah berasid. Penggunaan kompos jerami boleh mengantikan semula kehilangan fosforus di dalam tanah disebabkan oleh larut resap tanah asid tropika dengan meningkatkan ketersediaan fosforus dan mengurangkan pengikatan fosforus tanah.

Kata kunci: Fosforus, kompos jerami, penyerapan, desorpsi, kapasiti buffer pH

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LIST OF ABBREVIATION AND SYMBOLS

P	Phosphorus
N	Nitrogen
K	Potassium
Al	Aluminium
Zn	Zinc
Fe	Iron
S	Sulphur
Si	Silicon
Na	Sodium
C	Carbon
Ca	Calcium
Cu	Copper
Mg	Magnesium
HPO_4^{-}, HPO_4^{2-}	Orthosphosphate
KCl	Potassium chloride
NaOH	Sodium Hydroxide
HCl	Hydrochloric acid
H_2SO_4	Sulphuric acid
$Al(OH)_3$	Aluminium hydroxide
Fe_2O_3	Iron oxides
pH	Potential of hydrogen
EC	Electrical Conductivity

CEC	Cation Exchange Capacity
ATP	Adenosine triphosphate
ANOVA	Analysis Variance
SAS	Statistical Analysis System

CHAPTER 1

INTRODUCTION

1.1 Background

Phosphorus (P) is an essential crop macronutrient because of the relatively large amount of P required by plants. It plays important roles in all major metabolic process in plant including photosynthesis, energy transfer, macromolecular biosynthesis and respiration (Khan et al., 2010). Phosphorus also improves the efficiency of N uptake by the plants and can help to reduce risk of groundwater pollution due to nitrate leaching (Plaster, 2003). In agriculture, P usually holds the important effect in root growth because it is usually applied as the starter fertilizer. However, mismanagement of soil P can cause water quality deterioration (Bai et al., 2017). This is because the P is a primary cause of long terms risk on the environment in terms of eutrophication. Therefore, the good use and management of P in farming systems is essential to reach large agricultural activity without threatening the environmental quality (Fink et al., 2016).

Phosphorus is abundant in soil in both organic and inorganic forms but its availability is restricted and low solubility. Inorganic P occurs in soil mostly in insoluble, precipitated forms where cannot be absorbed by plants (Zhou et al, 2001). Plants can only take up P when it is dissolved in the soil P solution. Many soils contain large amounts of phosphate, but only 0.1% of the total phosphate exists in a soluble form available for plant uptake (Zhou et al, 2001). The insoluble phosphate is unavailable for plant because of P fixation. Phosphate in the fixed P pool can remain in the soil for years and may have very little impact on the soil fertility (Zhou et al, 2001).

In acidic soils, aluminium (Al) is the dominant ion that will react with P, where P will be precipitated by free Al^{3+} in the soil solution (Simonsson et al., 2018) and will result in insoluble compounds of phosphate and generally unavailable for plant uptake (Poulo et al., 2017). When the soil pH declines to about 6.0, Al^{3+} would react with water to form hydrogen ion (H^+) and aluminium hydroxide ($Al(OH)_3$) compounds. Aluminium hydrolysis can lower the pH of soil about 4.0 and can reach toxic levels in the soil (Plaster, 2003). Aluminium occupies most of cation exchange sites and can cause high concentration in the soil solution. Once the Al toxicity reaches in the soil, it severely inhibits the plant root growth. The simplest way to ensure proper pH of the soil for certain crop is liming procedure. One of the purposes of applying lime to agricultural fields is to enhance the availability of P to crops (Simonsson et al., 2018).

Sorption of P is the removal of ionic P, $H_2PO^-_4$ or HPO_4^- from solution by the reaction with solid phase of the soil while desorption is process of releasing of ions or molecules from solid into solutions. Desorption of P in soils is considered as the reverse process of the sorption in the soil. The sorption of P by a soil can be measured to determine the potential of P fixation, the extreme of soil P saturation and to estimate the risk of P loss (Nwoke, Vanlauwe, Sanginga, Osonubi and Merckx, 2003). There are two methods can be used to measure the P sorption, exposing soil to a high P spike or single point sorption or determining a sorption isotherm by exposing a series of soil samples to different concentration of P by calculating the maximum P sorption (Essington, 2004).

Phosphorus can be easily adsorbed and immobilized freely by organic and inorganic soil involving physical attraction, chemical adsorption (Wang & Liang, 2014) and can measured by cation exchange capacity (CEC). The P adsorption and desorption is the main aspects of the chemical behaviour of P in the soils. It is also an important internal cycling for soil fertility problem (Wang & Liang, 2014). There are some studies approved that soil organic materials can increase or decrease the P sorption of soil. Trazzi, Leahy, Hayes, & Kwapinski (2016) concluded that biochar application to soil can be altered P availability by changing P sorption and desorption process. These P adsorption and desorption were dependent on soil acidity, the type of organic materials, concentration of P and the amount of biochar added to the soil.

Plant available P in calcareous soil is commonly performed by removing solid phase P and test using extraction procedure. Critical soil test values may be affected by variation in sorption and buffering behaviour of soil. Sorption isotherm is the methods used to determine and deriving the buffering capacity in relation to determine the P availability in labile solid phase. The buffering capacity shows better correlations with uptake by plants. The buffering capacity is the important role in P uptake by plants especially during plant growth stage and soil adsorption and desorption (Shirvani, Shariatmadari, & Kalbasi, 2005).

Rice straw is the vegetative part of the rice plant which involves cutting the grain after harvest. In Malaysia, rice straws are managed through open burning and cause the environmental pollution (Rosmiza, Davies, Aznie, Mazdi, & Jabil, 2014). This is because the rice straw is left on the field before the next ploughing. In agriculture, the straw can be used as compost and can be the soil absorber and helps to improve the fertility of the soil (Park, Lee, Ryu, & Park, 2014). Food and agriculture Organization of United Nations stated that the rice population in Malaysia in year 2017 is 5842 000 tonnes. The ratio of grained harvested to straw is 0.45: 0.55. The ratio of grain yield and straw is almost same (Rosmiza et al., 2014). The only 3, 176, 593.2 tonnes production of rice straw in year 2011 and maybe the production of rice straw will increase as the rice production increase.

Compost is organic materials added to the soil as fertilizer and soil amendment. The usage of compost as the organic amendment can help to improve soil health and its fertility. Besides, by adding compost to the soil, the soil tends to adsorb the nutrients because they are attracted to humus particles which are negatively charge. Humus also has the ability to breakdown the bond that occurs between aluminium ions and P ions (Plaster, 2003). Soil amendment can improve soil water holding capacity or water infiltration in the soil. The biochar compost had the potential to enhance the soil fertility and as the preventer for nutrient leaching. Besides, the presence of biochar can decrease the P-fixation and P sorption on Fe-oxides and thereby enhance P bioavailability (Trazzi et al., 2016).

Buffering capacity in soil is the capabilities of soil to resist changes in pH by either absorb or desorb H^+ and OH^- ions. Clay soils are the soil tends to have higher buffering capacity in soil compared to sandy soils because higher organic matter content. In acidic soil, compost and other soil amendment are used as the medium to help soil to resist change in pH due to increase of Al and H in soil solution. Small or large changes in pH can influence the plant in many ways especially diminishing the nutrient in soil which are very useful for plant growth. Therefore, increasing in buffering capacity can also increase the soil pH by acid cations of the CEC increases in the soil solution (College of Tropical Agriculture and Human Resources [CTAHR], 2017). This reason cause the Al and H will dissolve and release these cations as they are removed from the exchangeable pool.

1.2 Problem Statement

The direct or indirect influence of rice straw compost on P in soil has rarely been reported, especially P sorption and desorption. Understanding the fundamental of the interaction between compost and soil, as well as the mechanism of the increase in soil P availability is essential.

1.3 Research Question

Can application of rice straw compost changes the degree of P sorption and desorption in soil and influence the soil maximum P buffering capacity?

1.4 Hypotheses

1)

H_0 - The degree of soil P sorption and desorption remain unchanged upon application of rice straw compost

H_1- The degree of soil P sorption and desorption change upon application of rice straw compost.

2)

H_0- The soil P maximum buffering capacity value remain unchanged upon application of rice straw compost

H_1- The soil P maximum buffering capacity value change upon application of rice straw compost.

1.5 Objectives

1) To sample and characterize the soil sample to be used in this study
2) To determine the changes in the soil P sorption and desorption upon application of rice straw compost.
3) To determine the soil P maximum buffering capacity that is resistant to change in P concentration of the soil of the labile solid phase.

1.6 Scope of Study

To determine the way to reduce P sorption in soil by adding compost and enhance the availability of P in the soil.

1.7 Significance of study

Provide fundamental understanding on the mechanism of P sorption and desorption using organic amendment such as compost. The compost is use to reduce the P fixation in tropical acid soil. Its help by alter the pH of soil thus enhance the availability of P in soil and crops. The organic matter in compost will influenced the P sorption and desorption process in soil because microorganisms in organic matter can mineralized organic P into the inorganic P which are available for plant uptake. Besides, compost can increase P desorption in soil due to negatively charge provide by humus particles in compost which favour to adsorbed cations (Al^{3+}, Fe^{3+}) in acid soil instead of anions (PO_4^{3-}).

CHAPTER 2

LITERATURE REVIEW

2.1 Phosphorus

The study of P is always been intensive and in a large scale since P is an essential plant nutrient that plays role in plant growth (Garland et al., 2018), plant metabolism, sustaining the ecology and the fertility of the soil and can helps in environmental stability.

2.1.1 Phosphorus Cycle

Phosphorus cycles in soil through several processes and in several forms. The P cycles is slow and differ from other major biogeochemical cycles because it does not include a gas phase. Most of P in nature systems like soil and water exists as phosphate (CTAHR, 2017), a chemical form in which each P atom are surrounded by 4 oxygen

(O) atoms. The phosphate (PO_4^{3-}) can interact with acidic soil and exists as $H_2PO_4^-$ and as HPO_4^{2-} in alkaline conditions. The largest reservoir of P is in rocks. The rain and weathering process will cause of removal inorganic phosphates is then distributed in soil and water. The plants take up the inorganic phosphates from the soil and utilized by animals that consume that plants (Pagliari, Kaiser, Rosen, & Lamb, 2009). Most of the phosphate use by living organisms will incorporate into organic molecules such as DNA. The organic phosphate absorbed by animal tissue through consumption eventually returned slowly to the soil through urine, faeces and also when animal or plants residues decay in soils. The organic phosphate can be made available to plants by the bacteria that breakdown organic matter to inorganic forms of P. The conservation of organic to inorganic phosphate is known as mineralization. The reverse reaction of mineralization is immobilization process. Phosphorus can drain away from soil by heavy rain into waterways and oceans. Once there, it can be incorporated into sediments over time.

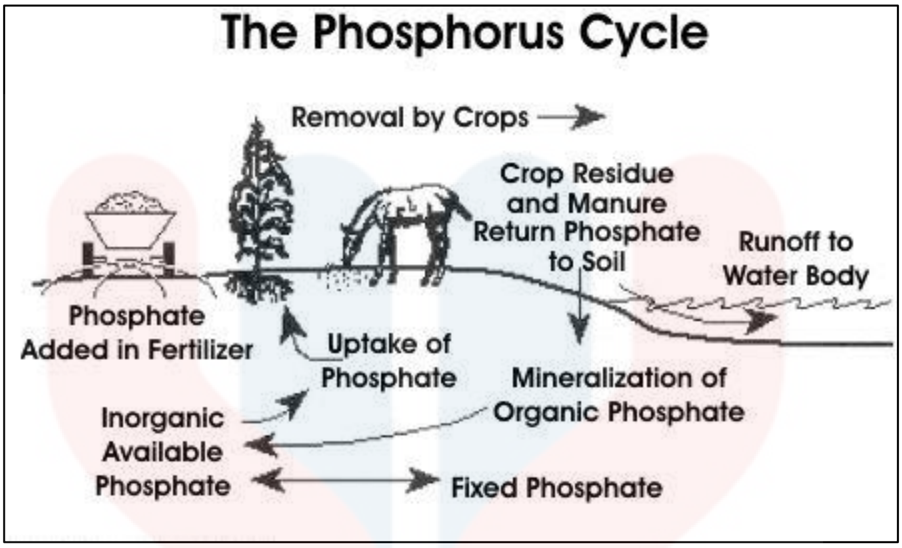

Figure 2.1: Phosphorus Cycle

Source: Pagliari et al., 2009

2.1.1.1 Mineralization and Immobilization of Phosphate

In P cycle, the mineralization and immobilization process are important for supplying available P to plants where occurs simultaneously in soil. The mineralization is the process of microbial conversion of organic P to inorganic P, forms of plant available P known as orthophosphate. Meanwhile, immobilization reaction is the opposite reaction of mineralization. The immobilization is available P forms are consumed by microbes and turning the P into organic P. The Carbon(C):P ratio determines whether there is net mineralization or net immobilization. When the C:P ratio is less than 200:1, net mineralization take place or prevails. Net mineralization shows that there is enough P in the soil to sustain both plants and microorganisms

(CTAHR, 2017). Temperature, moisture and aeration affect the rate of mineralization of P hence decomposition of organic matter occurred.

2.1.1.2 Leaching

Highly weathered soils generally can cause compaction and allow water to move and drain nutrients in soil freely. Agricultural systems can experience phosphorus losses as the result of erosion by wind and runoff water. Erosion by wind can leach nutrients that contain sorbed-P to water systems, where P can desorb and incorporated into sediments later on. (CTAHR, 2017). Previous research are mostly concentrate P loses from soil to water by erosion and surface runoff, as P losses from leaching were thought to be insignificant. However, leaching can affect environment because eutrophication might be start (Fortune, Lu, Addiscott, & Brookes, 2005).

Leaching is removal of dissolved P from soil by vertical water movement. Phosphorus leaching can occur if the soil reaches maximum P holding capacity, especially when the fertilizers are over applied. The coarsely textured soils, sandy soils are most susceptible to P leaching (CTAHR, 2017). The impact of P leaching from agricultural practices is the contamination of ground water resources due to P carried in eroded soil from fields. The transported of P-rich sediments lead to P into water solution and give harmful to the aquatic life (Silva et al., 2000). Once the organic matter decompose, it will releasing P to the soil more quickly in warm, humid climates than in cool, dry climates. Well aerated soil can release P faster than saturated soil which is not enough oxygen (United States Department of Agriculture [USDA], 2018).

2.1.2 Importance of P

Phosphorus is a major element that performs vital functions for substance, growth and development of plants and animals. Phosphorus is usually in the form of ion that becomes the essential nutrient for organisms. It is involve several key plant functions, including energy transfer, photosynthesis, transformation sugars and starch and nutrient movement within the plants (Pagliari et al., 2009). Phosphorus is a component of the complex nucleic acid structure and adenosine triphosphate (ATP) of plants and animals which regulate protein synthesis and involve in plant reproduction system.

Phosphorus is needed in root development, so it often used as starter fertilizer those applied at planting. Furthermore, P helps plant use water efficiently by improving water uptake by healthy root, as the self defence mechanism from cold and disease, aids blooming and fruiting and improved the quality of the fruit. In tropical, most of the soil contains high concentration of total P, but very little are available to plants. Phosphorus deficiency becomes the second most important problem to soil fertility throughout the world (Pagliari et al., 2009).

Plants deficient in P are stunted in growth and often have an abnormal dark green colour, hence application of inorganic P fertiliser is used to control this problem. The low use efficiency in inorganic fertilizers has increased the alternative sources of P. One method is approaches to provide the soil with optimum concentration of P and increase the uptake of P by plants is the introduction of phosphate-solubilizing microorganisms in agriculture fields (Pagliari et al., 2009) and the application of organic materials like manure, compost and plant residue.

2.2 Form of P in Soil

2.2.1 Solution P Pool

Phosphorus exists in many different forms in soil. The solution P pool is the small P pool and usually contain mix of plant available inorganic P, organic P, adsorbed P and primary mineral P (CLAS, 2005). These P forms may be taken up by plants from sites for P runoff and leaching process. Many soils contain large amount of phosphate but much of it not available for plant uptake because insoluble p are not free for plant uptake due to P fixation. The weathering, mineralization and desorption helps in increasing available phosphorus in soil. Meanwhile, the immobilization, precipitate and adsorption decrease plant available P. The phosphate become precipitate when available inorganic P react with Al, Fe and calcium (Ca) and produce phosphate minerals. This situation causes P deficiency in the solution P where can restricting crop yields (Trazzi et al., 2016) if the pool were not being continuously replenished by active and fixed P pools. The P availability is low in many tropical soils make plants developed adaptation to improve access to it. These include mycorrhizal associations, specialised root system, longer root hair and exudates given off roots and mycorrhizae that free P. While these can be the effective responses in natural ecosystem but growers must added phosphate fertilizer to compensate for fixation (Plaster, 2003).

2.2.2 Active P pool

Active P pool is the inorganic P that is attached to small particles in soil. P can react with element such as Ca and Al to form soluble solids. Plant uptake the inorganic P from solution P pool and cause the concentration of inorganic P decrease. For backup, the inorganic P from active P pool will release and available for plant use. As the solution P pool is small and limited, the active P pool becomes the main source of available P. Organic P in active P pool is easily mineralized for continuous supply the inorganic P to the solution P pool. According to Pagliari et al (2009) , soil cannot hold more P when the solution concentration reaches between 60 to 90 mg L^{-1} because most of the sorption sites are occupied. Soil particles can acts in two sources either as desorption or sorption of phosphate to the surrounding water. Such sources are form depend on conditions.

2.2.3 Fixed P pool

Phosphorus fixation reactions occur rapidly in soil profiles. This reaction usually involves dissolve P anions with the soil. Fixed P pool usually consists of inorganic P which are in crystalline structure and less soluble than P compound available in active P pool (Pagliari et al., 2009). Phosphorus deficiency cause much of the P applied as fertilizer. Significantly the fertilizers will provide good result for P availability in soil but it not remains for long period due to faster reaction between fertilizers with soil profiles. The P fixed in soil as calcium iron or aluminium phosphate which relative insoluble and unavailable to plant uptake (Trazzi et al., 2016).

2.2.4 Availability of P in Soil

In agriculture, the availability of P in soil can be determined with soil test. The soil test commonly used to analyse and estimate how much phosphate will be available for crops. However, it also can used to determine fertility of soil. Different soil type consists different in the availability of plant nutrient. Sometime a field may contain a low level of one nutrient and high level of another nutrient (Plaster, 2003). Such variations are usually due to difference in pervious fertilizer, losses of soil surface by erosion or leaching.

Phosphorus availability can be determined by a basic three steps, process of extraction, measurement and interpretation (Plaster, 2003). Phosphate is extracted by filtering water or with extracting solution that contains an acid and complex agent through soil sample and it is determined per unit mass of soil. Next, concentration of P and pH are measured in the extracted solution using pH meter and spectrophotometer rapidly which provides most accurate measure of a soil's acidity or alkalinity. When the soil pH is less than or equal to 7.4, the Bray-1 P test is suitable calibrated for acidic soils, meanwhile in Olsen test has been calibrated for alkaline soil where soil pH is greater than 7.4. Bray-1 and Olsen test are availability index which have the goal to estimating the amount of P from the both alkaline and acid solution and active pool that can use (Plaster, 2003).

2.2.4.1 Soil P Solubility and Water Quality

Inorganic P is low solubility element in water systems. A report by Wang & Liang (2014) stated that the increasing of P concentrations in land runoff and drainage to surface water can cause eutrophication. Most of phosphate in runoff is in dissolved form, the readily available for algae growth. The excessive algae growth will cause algae bloom in water ecosystems and once the algae die, it started to decompose. The algae residue will use dissolved oxygen in water cause the competition with the aquatic life. The aquatic life will die and significant result in deterioration of water quality.

2.3 Factor Affecting P in Soil

Several factors affect how well the plants take up P, namely temperatures of the soil, soil pH and the features of the soil.

2.3.1 Temperature

The availability of P is influenced by soil temperature. At low temperature, P may be deficient while at high temperature the P supplying capacity will greater. Soil microorganisms are the foundation of the Earth’s biosphere and play important and unique roles in the cycling of C, N, S and P, as well as of various metals in the world (Xu et al., 2015). These kinds of soil microorganisms have their favourable temperature. They will plays role in soil organic matter for decomposition. Decomposition of soil organic matter is important for P release in the soil and soil temperature considered as one of the factors that influencing the soil organic matter decomposition (Dan et al., 2016). The mineralization rate of soil organic matter increased in warm humid climate than in cool climates. Warm climates give significant result for availability of inorganic P in soil. According to Plaster (2003), soil temperature can be managed by applying mulches on soil. Light coloured of organic mulches like straw insulate the soil and reflect the sunlight. This lower the soil temperature and improving the plants growth as well as increase the P availability in soil.

2.3.2 Soil pH

Soil pH is the interaction of the soil mineral ions in solution and cation exchange. Different reaction will cause different pH ranges and soil elements change form as a result of reactions in the soil. Phosphorus will be fixed with Al and Fe at the lower pH, and with Ca at higher pH of soil. Hence, the liming is required when the soil pH is higher. One of the purposes of applying lime to agriculture fields is to enhance the availability of P in soil and crops (Simonsson et al., 2018). The P is most available to plants between a pH of 5.0 to 7.0.

2.3.3 Type and Texture of Soil

The most fundamental soil property which influenced soil trait is texture. Tropical soils type is clay, even clay have been leached out and replace with Al-oxides. Several studies stated that the clay can increase the nutrient holding capacity (Schjønning, Mcbride, Keller, & Obour, 2017; Tahir & Marschner, 2017). This is because clay has smallest soil particles. Clay can bond the nutrient chemically to their surface and hold P for longer period due to its smaller pores before leaching and runoff. The smallest pores give advantages in lower infiltration rate. The soil with high amounts of clay content will fix more P than those containing less P.

2.4 Phosphorus Sorption and Desorption

2.4.1 Factor Affecting Sorption and Desorption of Phosphorus

The soil characteristics that influence P sorption and desorption include soil mineral type, particles size, soil organic matter (Wang & Liang, 2014) and soil temperature. Soil mineral type has great effect on P sorption because they contain many amorphous materials. Besides, the highly weathered soil gives the same great effect in P sorption capacities due to high amount of Al and iron oxides (Fe_2O_3). Since phosphate is an anion, particles that create an anion exchange capacity will form the strong bonds with phosphate in soil.

Clay soil have tremendous amount of surface area that P sorption can take place. Besides, the clay soil contains Al and Fe_2O_3 where these ions are important in P fixation in soil phases. Soil organic matter influenced the sorption and desorption processes in the soil because organic matter which are contain bacteria can mineralized the organic P into inorganic P. As the result, sorption process will decrease because the P is available to crops. The soil sample amended with soil organic matter can increase P desorption rate especially when the higher concentration of soil organic matter is applied to the soil (Wang & Liang, 2014). Changes in soil pH are significantly influences P sorption and desorption in soil. Increasing pH of soil resulted in a decrease of sorption equilibrium constant due to increase in CEC as well as increase P sorbed.

2.4.2 Sorption and Desorption Isotherm

Phosphorus sorption and desorption isotherm have been widely used as one of the methods for estimating the phosphate requirement of soils (Fink et al., 2016). These isotherms are used for measuring both the intensity of soil P and soil capacity to added P. Besides, usually P sorption and desorption can calculated the replenishing ability of soil to supply P such as fertilizer or organic amendment to the soil solution. These are to important factor in P supplying capacity of soil to plants. Sorption isotherm has an empirical relationship used to predict how solute can be adsorbed by activated phosphorus.

Phosphorus desorption is a process determining inorganic P bioavailability (Nziguheba, Palm, Buresh, & Smithson, 1998). However, in order to use the desorption process in nutrient uptake models, a P sorption and desorption isotherm is required. An isotherm describes the amount of P on the solid phase or at equilibrium solution.

2.4.3 Freundlich Isotherms

The earliest known relationship describing the sorption isotherm is Freundlich isotherm. This isotherm can be used in sorption from dilute form solutions. The isotherm is expressed by the following equation

$$q_{\mathrm{e}} = K_{\mathrm{x}}\, x\, C_{\mathrm{e}}{}^{1/2} \qquad (2.1)$$

where C_e is the equilibrium concentration in the solution (mg/dm³), q_e is the equilibrium adsorption capacity (mg/g), K_x and 1/n are empirical constants. K_x is the adsorption value, the amount adsorbed at unit concentration, that is, at 1 mg/dm³. It is characteristic for the adsorbent and the adsobate adsorbed (Zhang, Hong, He, Gan, & Ho, 2011).

2.4.4 Langmuir Isotherms

Langmuir isotherm is published by Irving Langmuir in 1916. The Langmuir sorption isotherm is the best known of all isotherms describing sorption in soil. The theoretical Langmuir isotherm is usually used to describe sorption of a solute from a liquid solution as the equation is

$$q_e = \frac{q_a \ x \ K \ x \ C_e}{1 + K \ x \ C_e} \qquad (2.2)$$

Where q_e is the equilibrium adsorption capacity (mg/g), C_e is the equilibrium liquid phase concentration (mg/dm^3), q_a is the maximum adsorption capacity (mg/g) and K is adsorption equilibrium constant (dm^3/mg). Langmuir isotherm derived from a proposed kinetic mechanism (Bai et al., 2017).

2.5 Agriculture Waste

2.5.1 Rice Straw

Rice (*Oryza sativa*) has become the second most important crops in the world after wheat. Rice is grown as the staple food (Rajamoorthy, Rahim, & Munusamy, 2015) half the world's population that contributes to 20% of the total human caloric intake daily. However, total caloric intake for the Asian population is around 70% where mostly rice production comes from Asian countries such as China, India, Indonesia, Bangladesh, Vietnam and India (Jamal, Kamarulzaman, Abdullah, Ismail, &

Hashim, 2014). The increasing population in Asia lead to increase the production of rice to meet the demand in the future.

Rice straw is rice residue which not fully utilised in Malaysia (Shafie, 2015). Rice straw is non-edible product, frequently left on the field after harvesting process. In Malaysia, rice straw disposed of mostly by open burning. There are various potential uses for rice straw that can be developed and give benefits to Malaysia’s rural economy (Rosmiza et al., 2014). For achieving more ecological sustainability agricultural practices, farmers need to understand benefits of rice straw and that will encourage them to utilise this by-product apply for their fields. Rice straw can be used as compost and soil amendment in lowland paddy field. Cuevas, Orajay, & Lagman (2014) prove that the use of rice straw compost can reduce soil copper (Cu) toxicity in lowland paddy fields. Besides, in Malaysia, rice straw resources have been utilized for reducing fossil fuel consumption. Rice straw-based power generation in Malaysia is one of biomass that used to generate electricity (Shafie, Masjuki, & Mahlia, 2014).

In rural areas, straw often used in traditional ways such as animal feed, fertilizer and for domestic uses. Based on previous research, the soil quality can be improved by returning the crop residue to the soil. It has potential to reduce the erosion, stabilizing soil structure and improve water retention. Rice straw potentially has a high nutrient value and can be more economically beneficial. The nutrient content in rice straw is represented in Table 2.1.

Table 2.1: Nutrients content in rice straw

Nutrient Content	**Percent (%)**	**Nutrient Content**	**Percent (%)**
Nitrogen (N)	0.65	Magnesium (Mg)	0.20
Phosphorus (P)	0.10	Calcium (Ca)	0.30
Potassium (K)	1.40	Iron (Fe)	0.035
Zinc (Zn)	0.003	Manganese (Mn)	0.045
Sulphur (S)	0.075	Copper (Cu)	0.0003
Silicon (Si)	5.50	Boron (B)	0.0010

Source: Rosmiza et al., (2014)

2.6 Composting

Compost is one of the organic amendments and fertilizer which contain the mixture of various decaying organic substances. Compost contain a combination of nutrient are readily used by plants. However, the main concern about compost is over their environmental sustainability (Weindorf et al., 2011).

Composting is the nature's way of recycling. On the other words, composting is the process of aerobic decomposition of biodegrades organic waste such as household waste, manure and fungi which turn it into a valuable organic fertilizer. Composting is a natural biological process that performed by various microorganisms, bacteria and fungi with presence of oxygen (Duong, 2013). The effectiveness of the composting the material are dependent upon the environmental conditions. Finished compost can be classified as organic fertilizer that contains primary nutrients available for plant. High quality of compost can be used in agriculture because compost will improves the soil porosity, aeration, soil holding capacity, nutrient uptake and help reduces soil compaction (Weindorf et al., 2011).

2.6.1 Compost pH Buffering Capacity

Compost is a good form of fertilizer (Cuevas et al., 2014) that applying as limited substitute for lime in the potting media and also enhance the availability of P to crops (Simonsson et al., 2018). Most compost has pH of 7 to 8 and it operates best at that pH. Applying compost will not alter the soil pH. Organic amendment has high cation concentration and high H^+ buffering capacity (Costello & Sullivan, 2014). On the other words, compost has ability to buffer the pH which tends to keep pH of soil from sudden changes (Cuevas et al., 2014). In compost pH buffering have extra attachment sites which is provide as it raises CEC will help to absorb and retain nutrient at any chemical reaction.

Based on Costello and Sullivan (2014) research, the high bush blue berry with pH 4.5 -5.5 is the acid loving plant. The compost pH buffering is used to determine the quantity of acidity needed to reduce pH by one unit. To lower pH in alkaline compost need to develop compost acidification and make it suitable as soil amendment for high bush blueberry.

2.7 **Mechanism of Compost in Influencing the Soil Phosphorus Sorption and Desorption**

2.7.1 Ligand Exchange

Ligand exchange is the organic sorbates competing with P for mineral binding sites. Guppy, Menziea, Moody and Blamey (2005) stated that realistic application rates of organic matter such as manure can increase the available P in soil because of the addition P contain in organic matter. Based on previous studies, organic matter can effectively compete with sorption sites and it also can increase the sorption of P to its chelated metals cations. Similarly, increase in available P during composting of phosphate rock and organic matter largely reflect the mineralization of organic P (Mahimairaja, Bolan & Hedley, 1994), thus increase the desorption in soil.

2.7.2 Buffering Soil Acidity

The improvement of soil P availability is achieved by applying organic matter to the soil. *Tithonia spp.* is the plant biomass that proved can increase the soil available P and maize yields comparable to inorganic P inputs and can reduce P fixation. Apart from that, ameliorating P fixation with organic matter is thought to reflect decreases in binding sites or exchangeable acidity. This can cause the organic matter complexation of exchangeable Al^{3+} and consumption of H^+ via decomposition process and organic matter buffering (Cuevas et al., 2014). Soil can absorb more acid or base without significance change in pH if the soil buffering capacity is higher. The higher soil buffering capacity of soil caused higher of CEC in soil. When the CEC increase, it will provide the extra attachment site mean that able to retain P in long periods.

2.7.3 Potential P Source *via* Mineralization

The microbial biomass can serve as a labile reservoir of the plant available P. The application of organic amendments and inorganic-organic mixture can increase the size of the microbial biomass (Malik, Marschner & Khan, 2012). Low-input systems can maximize the benefits of microbial P cycling by combinations of organic and inorganic P fertilizers rather than during separate application. The microbes contain in the organic fertilizer can react with the organic P in the soil. This process called mineralization process. Once, the mineralization occurs the available P for plant uptake will increase and the sorption of P will decrease. According to Moharana, Biswas and Datta (2015), the organic manures can synchronize nutrient availability where is it can reduce N losses as well as P-fixation. However, organic manure cannot meet the nutrient requirement for high yield crop because low content of P. The laboratory incubation experiment was conducted by Moharana, Biswas and Datta (2015) to study the N , P and S mineralization in soils amended with rock phosphate enriched composts and fertilizers over 120 days. The results show that rock phosphate enriched compost amended soil mineralized higher in N and S but the P mineralization very slow. Then the study revealed that the soil treated with RP enriched compost improved significantly the P mineralization with the progress of time, indicating that RP enriched compost released P for a longer period crop growth (Moharana, Biswas & Datta, 2015). As the conclusion, organic amendments help to minimize P sorption in soil.

2.7.4 Stimulating Biological Cycling of P

Phosphorus is element in biological reactions where the small changes in phosphorus availability can caused major impacts on ecosystem function and structure. In soils and ecosystems, P is derived from the parent rocks. Phosphate is insoluble and it is eventually weathered and leached out so that many soils are P deficient (Tiessen, 2011). Furthermore, deforestation nowadays can alter the P cycle in many ways and disturb the ecosystems. The P reservoir, the originally nutrient store in soil are washed away by heavy rain because of the changes in soil structure which are cannot hold the nutrient efficiently. Many high productivity agricultures rely on P fertilizer which is cause a lot of money. Good management practice is crucial both in fertilisation practices and efforts to recycle P from waste (Tiessen, 2011). Compost has two main benefits on soil which are replenish soil organic matter and supply plant nutrients. The nutrients that supply to soil are including P and N. Inputs of organic matter may enhance the biological cycling of P because the organic matter has the beneficial microbes stimulate the mineralization process in soil. According to Duong (2013), the organic matter can indirectly improve the soil structure by increasing microbial activity with the production of microbial slime and fungal hyphae bind aggregates together. Biological cycle of P can play the significant role in provisioning plant available P, in particular for weathered soils with high potential for P fixation. Compost can stimulate the biological cycling more economic, efficiently and environmentally-friendly because compost will slowly decompose and release nutrients where are more effective to increase organic matter and have long lasting effects (Duong, 2013).

CHAPTER 3

METHODOLOGY

3.1 Soil Sampling

The uncultivated soil in Universiti Malaysia Kelantan Jeli Campus area was sampled at 0-20cm. The soil samples passed through a 2-mm sieve after it was being air-dried and crushed manually for laboratory analysis.

3.2 Soil Analysis

The soil was analysed for soil bulk density, soil pH, soil texture, total organic matter, total carbon, soil exchangeable Fe, soil exchangeable acidity, soil electrical conductivity (EC), and soil available P.

3.2.1 Soil Bulk Density Determination

The bulk densities at soil depth 0-20 cm were determined by coring method. The core which filled with soil was weighed and oven-dried for 24 hours at 150°C. After 24 hours, weighed again the coring with soil and oven-dried were repeated until the weight was constant. The bulk densities of the soil were calculated using formula that described by Dixon & Wisniewski, (1995):

$$\text{Bulk density (g cm}^{-3}\text{)} = \text{Dry oil weight (g) / Soil volume (cm}^{3}\text{)} \qquad (3.1)$$

3.2.2 Soil Texture Determination

A hydrometer method was used in determining the soil texture (Bouyoucos, 1962). A 50 g of soil was placed into blender cup. A 4 M NaOH was dropped wisely to adjust the pH until it becomes 10. Distilled water was poured into the blender cup until it reached 10 cm of the top rim. Afterwards, the soil was allowed to blend and mixed well for 15 minutes. The soil suspension was transferred into 1 L of measuring cylinder and the distilled water was added until the volume up filled to 1,130 mL. The stirring rod was used to stir the suspension for 40 seconds. Then, the hydrometer was placed into the soil suspension and the reading on hydrometer stem was recorded. The hydrometer was removed from the suspension. The second reading was taken after the suspension was stirred for the second time. The expected result was equivalent to the amount of silt and clay in grams of the soil sample. The same steps were repeated for third reading after the suspension left for 2 hours. The calculation of the soil texture is shown below:

Percentage of sand + Percentage of silt + Percentage of clay = 100%

For 40 seconds reading:

$$\text{Percentage of silt + clay} = (a/50) \times 100\% = w$$

$$\text{Percentage of sand} = (100 - w)\,\% = x$$

After 2 hours reading:

$$\text{Percentage of clay} = (x/50) \times 100\% = y$$

$$\text{By different Percentage of silt} = w - y = z \quad (3.2)$$

3.2.3 Soil pH and Soil Electrical Conductivity (EC)

Measurement of soil pH using a potentiometric method determines the degree of acidity or alkalinity in soil suspended in water (Peech, 1965). In this method, the ratio of 1:2.5 (soil : distilled water suspension) was used to measure both, soil pH and EC by using pH and EC meter. A 40 mL of distilled water was added to 16 g of air-dried soil in conical flask. The samples were shaken using mechanical shaker at 180 rpm for 15 minutes and left overnight for 24 hours. The pH and EC meter were used to determine pH and EC of the soil samples.

3.2.4 Soil Total Organic Matter and Total C Determination

The soil total organic matter and total C were determined using the dry combustion method (Tan, 2005). The initial weight crucible and the weight of crucible with 5 g of soil samples were recorded. The soil samples were ashed at 300 °C in the muffle furnace for 8 hours with temperature 550 °C. The soil samples were allowed for cooling down and the weight of samples after ash was recorded. The total organic matter and C calculation are shown below.

Calculation of Total Organic Matter:

$$\frac{\text{Initial weight of sample (g) – Final weight of sample (g)}}{\text{Initial weight of sample (g)}} \times 100\% \qquad (3.3)$$

Calculation of Total C:

$$\frac{\text{Initial weight of sample (g)} - \text{Final weight of sample (g)}}{\text{Initial weight of sample (g)}} \times \frac{58}{100} \qquad (3.4)$$

3.2.5 Soil Exchangeable Acidity and Al

According to Rowel (1994), the soil exchangeable acidity and Al were determined by using titration methods. A 10 g of soil and 30 mL of 1M potassium chloride (KCl) were placed in a beaker and left for 24 hours. After 24 hours the samples were filtered using Whatman Filter Paper No. 2 into 100 mL volumetric flask and the volume will make up to the mark using distilled water. Then, 50 mL of the soil extract was poured into 250 mL conical flask. Five drops of phenolphthalein indicator was added. The solution was titrated against 0.01 M NaOH until the pink colour appears. Then, the solution once again was titrated against 0.01 M HCl until the solution becomes colourless and this measured the soil exchangeable Al. The soil exchangeable acidity and Al were calculated by using the following calculation (Rowel, 1994).

$$\text{Exchangeable acidity (cmol kg}^{-1}\text{)} = \frac{0.2 \times \text{Titrate volume of } 0.01 \text{ M NaOH} \times 10}{\text{soil mass (g)}} \quad (3.5)$$

$$\text{Exchangeable Al (cmol kg}^{-1}\text{)} = \frac{0.2 \times \text{Titrate volume of } 0.01 \text{ M HCl} \times 10}{\text{soil mass (g)}} \quad (3.6)$$

3.2.6 Soil Extractable K, Ca, Mg, Na, Cu, Zn and Fe Determination

Soil extractable K, Ca, Mg, Na, Cu, Zn and Fe were extracted using Mehlich No. 1 Double Acid Method (Mehlich, 1953). A 5 g of soil sample was weighed and placed into 50 mL extraction vessel. After that, 25 mL of the extraction reagent were added. The solution was shaken about 10 minutes on a reciprocal shaker. Next, the supernatant was filtered into another beaker using Whatman Filter Paper No. 2 and the soil extract was collected. An atomic absorption spectrophotometer (AAS) will be calibrated before the extract undergoes aspiration and the reading was recorded. The calculation of soil exchangeable cation can use the equation below.

$$\text{Soil exchangeable cation (ppm)} = \text{AAS reading (ppm)} \times \left(\frac{\text{Volume of extractant (mL)}}{\text{Weight of soil sample (g)}}\right) \qquad (3.7)$$

3.2.7 Soil Available P Determination

The extraction of the soil available P was done by using Mehlich No. 1 Double Acid Method (Mehlich, 1953). In double acid preparation, 4 mL of concentrated HCl and 0.07 mL of concentrated H_2SO_4 were mixed into 1000 mL volumetric flask. A 5 g of soil sample were weighed and placed into 50 mL extraction vessel. After that, 25 mL of the extraction reagent was added and the soil solution was shaken about 10 minutes on a reciprocal shaker. Next, the supernatant were filtered into another beaker using Whatman Filter Paper No. 2 and the P extract will be collected. The molybdenum blue method was used to analyse the solution (Murphy & Riley, 1962) using UV spectrophotometer at 882 nm wavelength.

3.2.8 Soil Total N

The soil total N was determined using Kjeldahl method (Bremner, 1965) and was divided into 3 parts, digestion, distillation and titration. For digestion, 0.5 g of soil were weighed and added into digestion tubes. Next, 5 ml of concentrated Sulphuric acid (H_2SO_4) followed by 1 g of Kjedahl catalyst were added into the tubes. Then, the samples were shaken and calibrated for 30 minutes (Bremner, 1965). After that, the samples were heated at 400^{o}C for 1 hour. The samples were allowed to cool down. A 30 ml of distilled water was added to the samples and the volume was made up to 100 ml when the solution was cooled. For distillation, 10 ml of sample from the digestion part were added in distillation tube. Then, 10 ml of 40%, NaOH was added into the same tube and was distilled for 50 seconds. After that, the distillate was collected with another flask that contained 10 ml of 2% boric acid-indicator solution (Bremner, 1965). The flask that contained 10 ml of 2% boric acid-indicator solution were distilled until it reached 20 ml. For titration, the 20 ml solution from the digestion part was titrated against 0.01 M sulphuric acid (H_2SO_4) until the colour change from green to purple.

3.3 Compost Production

The rice straw composts were prepared from the mixture of rice straw, goat manure, molasses and chicken feeds. The rice straws were taken from paddy field at Pasir Puteh, Kelantan. These rice straws were lately bulked, air dried and shredded. The sampling of goat manure was taken from a dairy farm located in Kemahang, Kelantan. The composting process was carried out at open space of research area in Universiti Malaysia Kelantan, Jeli Campus. The 3 containers with 435 mm (height) x 425 mm (base) were prepared for composting purposes. The 12 holes were made with holes size 0.5 cm diameter, respectively. The rice straw compost was made by the mixture of 80% shredded rice straw + 10% of goat manure slurry + 5% of chicken feed + 5% of molasses in composting container. The preparation of rice straw compost was referred on the formulation ratio done by Ch'ng, Ahmed, Kassim, Muhamad, & Majid, (2013).

The composting processes were repeated for 3 replications and it took for 60 days for maturation.

3.3.1 Compost characterisation

The rice straw compost was analysed for pH, EC, total organic matter, total C, total N, P, K, Ca, Mg, Na, Cu, Zn and Fe. The procedure of analysing pH, EC, total organic matter and total C are similar to the procedure that described at previous sections.

3.3.2 Determination of Total P and K in Compost

Total P and K in the compost were determined by using the Single Dry Ashing Method (Cottenie, 1980). A 1 g of ground and dried sample will be weighed and place into the crucible. Then, the sample was placed in a muffle furnace for one hour and initially ashed at 300 °C. The temperature was raised to 520 °C after one hour and ashed for another 5 hours. Cool down the sample and add a few drops of distilled water followed by 2 mL of concentrated HCl. The sample was allowed to evaporate in the fume chamber using hot plate and 10 mL of 20% HNO_3 was added to the sample allowed heating process for one hour. Next, the Whatman Filter Paper No. 2 was used to filter the sample into 100 mL volumetric flask. For the K determination, the sample was aspirated into AAS and the absorbance reading was taken. The molybdenum blue method (Murphy & Riley, 1962) was used to determine the total P in the compost and analysed using UV spectrophotometer at 882 nm wavelengths.

3.4 Soil P Sorption and Desorption Determination

A laboratory assessment to determine the soil P sorption and desorption was carried out in the Physics laboratory at Universiti Malaysia Kelantan. The experimental design used in this study is completely randomized design (CRD) with three replications. The treatments evaluated in this study are as follows.

Table 3.1: List of treatment of P sorption and desorption.

Treatment	**Description**
T0	Soil only
T1	Soil + 5t ha^{-1} compost
T2	Soil + 10 t ha^{-1} compost
T3	Soil + 15 t ha^{-1} compost
T4	Soil + 20 t ha^{-1} compost

P sorption was determined based on the standard procedure described by Graetz Nair (2009) with some modifications on the concentrations of KH_2PO_4 used. A 2 g of soil only or soil with organic amendment were weighted into 50 mL centrifuge tubes.

Afterwards, 20 mL of 0.01 M KCl containing 0, 5, 10, 15, 20, 25 and 30 mg L^{-1} P as KH_2PO_4 were added into each of centrifuge bottles. The samples were replicated three times. Then, the samples were allowed to shake for 24 hours at 180 rpm in room temperature (27°C). The samples were centrifuged at 10, 000 rpm for 10 min. The supernatant with P was collected and determined using the molybdenum blue method (Murphy & Riley, 1962). The sorbed P was determined as the difference between initial amount of P added and the amount in the equilibrium solution. The P sorption data was fitted in Langmuir isotherm because of the degree of fitness into the isotherm. After P sorption analysis, the soil cake was allowed to air dry for 24 hours in room temperature. A total of 20 ml of 1M NH_4Cl was added after 24 hours and the soil cake in centrifuge bottle were dissolved using Vortex and the samples were shaken at 180 rpm for 10 min. Then, the samples were centrifuged at 10,000 rpm for 10 min for P desorption determination. The supernatant with P was collected and determined using the molybdenum blue method (Murphy & Riley, 1962).

3.5 Compost pH Buffering Capacity Determination

Compost pH buffering capacity was determined using the method mentioned by Costello and Sullivan (2014). The experiment was carried out after the soil P sorption and desorption experiment. A 5 g of the compost was weighed separately into 100 mL plastic vials using digital weighing balance. After that, 0,1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 mL of 0.25 M H_2SO_4 was added with water to bring the total liquid to 50 mL (1 : 10, Compost : water). Then, the samples was stirred for 10 s after acid addition and then stirred again for another 10 s for pH measurement using digital pH meter after 72 hours (Ch'ng, Ahmed, & Majid, 2016). The compost pH buffering capacity or the quantity of acidity needed to diminish pH by one unit was calculated as the negative reciprocal of the slope of the linear regression, soil or soil mixture pH (y-axis) versus acid addition rate (X-axis).

Compost pH buffering capacity (mol H^+ kg^{-1} soil) = - (1/slope)

where the slope was equal to the fitted slope linear regression line for each sample.

3.6 Statistical analysis

The Statistical Analysis System (SAS) have been used in this study to analyse the data collected in this research. The comparison of the treatment was measure using Tukey's HSD test at 5% level of probability while analysis of variance (ANOVA) was used to detect the treatment effects.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Characteristics of Soil and Rice Straw Compost

The selected physio-chemical properties of Rengam series (*Typic Paleudult*, clayey, kaolinitic, isohyperthermic) soil are used in Table 4.1. The soil was characterized as sandy clay loam with bulk density 1.25 g cm^{-3}. The soil was acidic with a pH of 4.54 and had lower concentration of available P (1.32 ppm). The low concentration of P was due to maximum sorption of P occurs in the acidic soil (Simonsson et al., 2018). The soil also showed relatively high concentration of Al and Fe in the soil because the pH falls lower than 5 (Zheng, 2010) and the ions occupied most of cation exchange sites (Table 4.1). The high concentration of Al^{3+} gave potential to P fixation due to dissolvement of P anions in soil. In acidic soil, the Al hydrolysed and became dominant ion where its ionic forms in soil solution can be very toxic to plants (Zheng, 2010).

The C/N and C/P ratios of rice straw compost were 19.92 and 125.38, respectively (Table 4.2).These ratios suggests net mineralization of the organic amendments (Ch’ng et al., 2016; Ch'ng, 2018).The rice straw compost also contains relatively high concentration of exchangeable cations especially K (8.71%), Ca (0.55%), Mg (0.345) and Na (10.6%) (Table 4.2). The near neutral pH of the compost (8.11) is very useful because it can increase the soil pH which contributed to improve soil fertility and quality. The higher organic matter in soil amendment can reduce Al toxicity and improve the P availability in soil (Simonsson et al., 2018).

Table 4.1: Selected physico-chemical properties of Rengam series soil

Property	Value obtained
Bulk density (g cm^{-3})	1.25
Soil texture	Sand: 63% Clay: 22% Silt: 15% => Sandy clay loam (*Typic Paleudult*, clayey, kaolinitic, isohyperthermic)
pH (Water)	4.54
Electrical conductivity (dSm^{-1})	0.03
Total organic matter (%)	5.46
Total C (%)	3.17
Available P (ppm)	1.32
Total N (%)	0.01
Exchangeable acidity ($cmol_c$ kg^1)	1.56
Exchangeable Al ($cmol_c$ kg^{-1})	4.90
Exchangeable K (ppm)	414.29
Exchangeable Ca (ppm)	793.87
Exchangeable Mg (ppm)	5,054.67
Exchnageable Na (ppm)	2,324.13
Exchangeable Fe (ppm)	1,083.60
Exchangeable Cu (ppm)	0.70
Exchangeable Zn (ppm)	3.27

Table 4.2: Selected chemical properties of the Rice Straw compost

Property	Rice straw Compost
pH	8.11
Electrical conductivity (dSm^{-1})	1.53
Total organic matter (%)	73.53
Total carbon (%)	42.63
Total nitrogen (%)	2.14
Total phosphorus (%)	0.34
C/N ratio	19.92
C/P ratio	125.38
Total K^+ (%)	8.71
Total Ca^{2+} (%)	0.55
Total Mg^{2+} (%)	0.34
Total Na^{2+} (%)	10.6
Total Zn^{2+} (µg/g)	54.2
Total Cu^{2+} (µg/g)	8.00
Total Fe^{2+} (µg/g)	1362.4
Humic acid (HA) (%)	6.50
Ash content (%)	12.81
Bacterial count (CFU g^{-1})	1.62×10^7

4.2 P Sorption and Desorption

The Langmuir equation is fit to describe P sorption ($R^2 \leq 0.80$) (Figure 4.1). Based on Figure 4.1, the P sorption isotherm curves shows that the amount of P sorbed into soil amendment increased at lower P equilibrium concentration (<10 mg L^{-1}) for all treatments (T0 - T4). The rangeability of sorption quantity declined as the P solution concentration increased (>10 mg L^{-1}) and remained constant at high equilibrium concentration because the sorbed P become less sensitive (Ch'ng et al., 2016) to the rice straw compost. The trend of P sorption in Figure 4.1 are most likely due to rice straw compost influenced the P sorption at low P concentration and finally reached sorption saturation condition as high P concentration. In other words, the responses of P are highly dependent on the initial level of soil acidity thus the result indicates that P sorbed for all treatments are increased at low P loading.

The S^m values which are represented the Langmuir maximum sorption capacity dropped from 0.341 mg kg^{-1} to 0.174 mg kg^{-1} (Table 4.3) when rice straw compost added with soil in various ratios. The decrease in P sorption is more pronounced at the higher compost application rate compared to lower compost application. The major components of compost, humic acid which contains carboxylic acid groups, can bind with positively charged multivalent ions such as Fe^{3+} and Al^{3+} (Pedra, Plaza, Garcia-gil, Polo, 2008). Due to that reaction, the cation exchange sites increased. Compost which incorporated with acid soil can help improve soil characteristics, soil CEC and soil pH. In addition, an increase of soil pH contributes to decreasing sorption of H^+ ions due to increase microbial activity and displacement of hydroxyl from sesquioxide surfaces by organic anions. Indeed, the positively charged nutrient may be absorbed to the soil organic matter and provide buffer against soil acidification. The soil surface become high in negatively charged as well as increase in anions repulsion and consequently decline in P sorption in soil. HPO_4^{2-} is anion that dominant in higher soil pH and very favour to be attracted by soil colloids (Haynes et al, 2000).

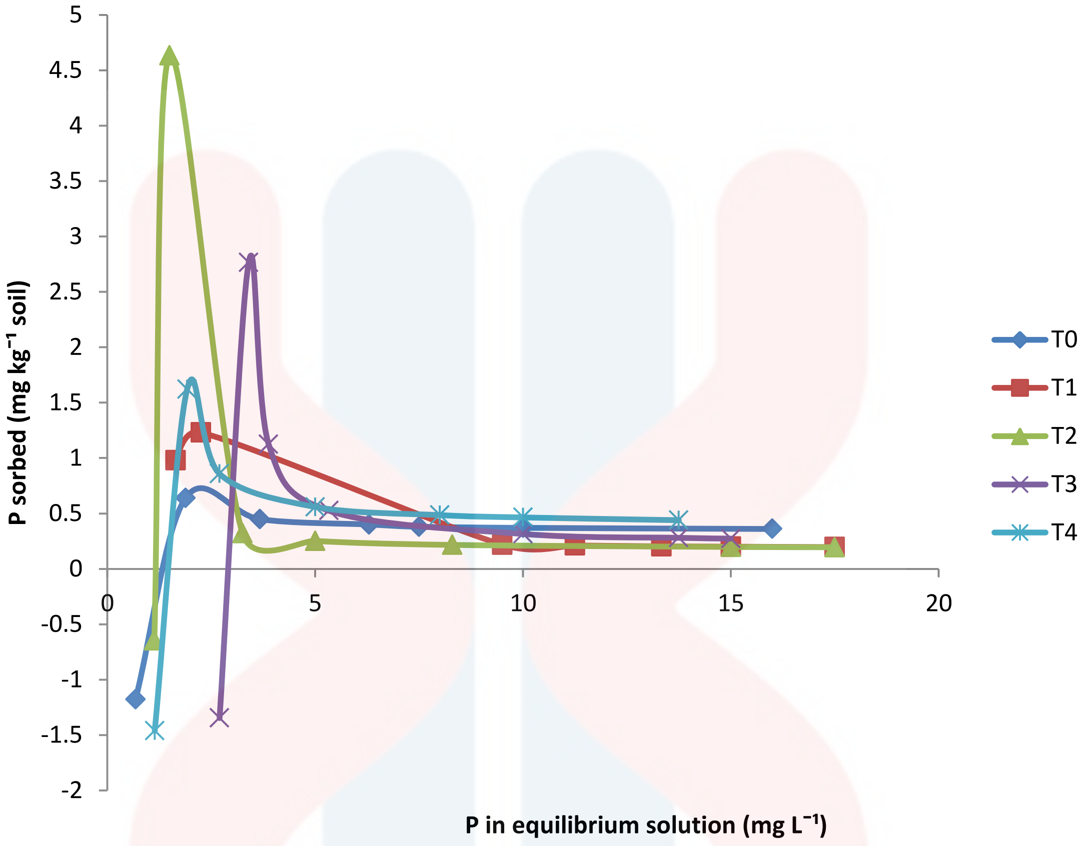

Figure 4.1: Effects of treatments on the soil phosphorus isotherms

The maximum buffering capacity (MBC) of soil calculated from the product of K^L and S^m in Langmuir equation (Maskina, Randhawa, & Sinha, 1980) was increased in T1, T2, T3 and T4 (Table 4.3). Based on the sorption isotherm curves, it is obviously that the rice straw ratios are influenced the sorption of P in the amended soils. The S^m and MBC of soil for P increased as compost content in soil increased. This result could be explained that organic matter, CEC and the availability of P in compost were high (Table 4.2). According to Mukherjee, Zimmerman and Harris (2011), anion exchange capacity of soil materials is lower than CEC the due to increase in surface negatively charge by soil organic matter and humus in compost. The compost surfaces are characterized by negative charged functional group which favour to adsorbed cations instead of anions such as PO_4^{3-}. These composition favours cation sorption which led to increase available P in soil since organic matter in compost had a large capacity toward cations.

Table 4.3: Phosphorus sorption parameters of the isotherm described by Langmuir equation

Treatment	Estimated by Langmuir Equation			
	K^L(L mg^{-1})	S^m (mg kg^{-1})	Maximum P Buffering Capacity (L kg^{-1})	R^2
T0	-1.141	0.341	-0.389	0.246
T1	-0.517	0.174	-0.089	0.352
T2	-0.693	0.178	-0.123	0.359
T3	-0.319	0.216	-0.068	0.804
T4	-0.689	0.397	-0.273	0.396

Desorption is the reverse reaction of sorption reaction in the soil. According to Figure 4.2, rice straw compost significantly increased P desorption rate in soil. The P desorbed increased are clearly shown in T1, T2, T3 and T4 which the soil treatments are applied with different ratios of rice straw compost. That significant increase was due to decrease of binding energy (K^L) (Ch'ng et al., 2016) which are calculated in Langmuir equation in Table 4.3. Evidence indicates that P desorbed in T1 is lower than T2 because the K^L value for T1 (-0.517 L mg^{-1}) is higher than T2 (-0.693 L mg^{-1}). Apart from that, the sorbed of P are significantly increased as the concentration of P increase.

The result in Figure 4.2 indicates that the P desorption are more effective when the concentration of P at 30 ppm.

The role of organic matter in raising P desorption in soil has always been attributed to the corporation and possible stabilization of the soil organic matter by free sesquioxides. In other words, the more negatively surface area exposed, the greater the tendency to adsorb the cations in soil. Higher soil pH has dominating the effect of P desorption rate in soil. This is because the organic amendment consists of organic functional group that can bind with different charge ions. To sum up, higher in soil pH is associated by organic amendment that can decreased the binding energy in soil thus increase the P desorbed in soil (Ch’ng et al., 2016).

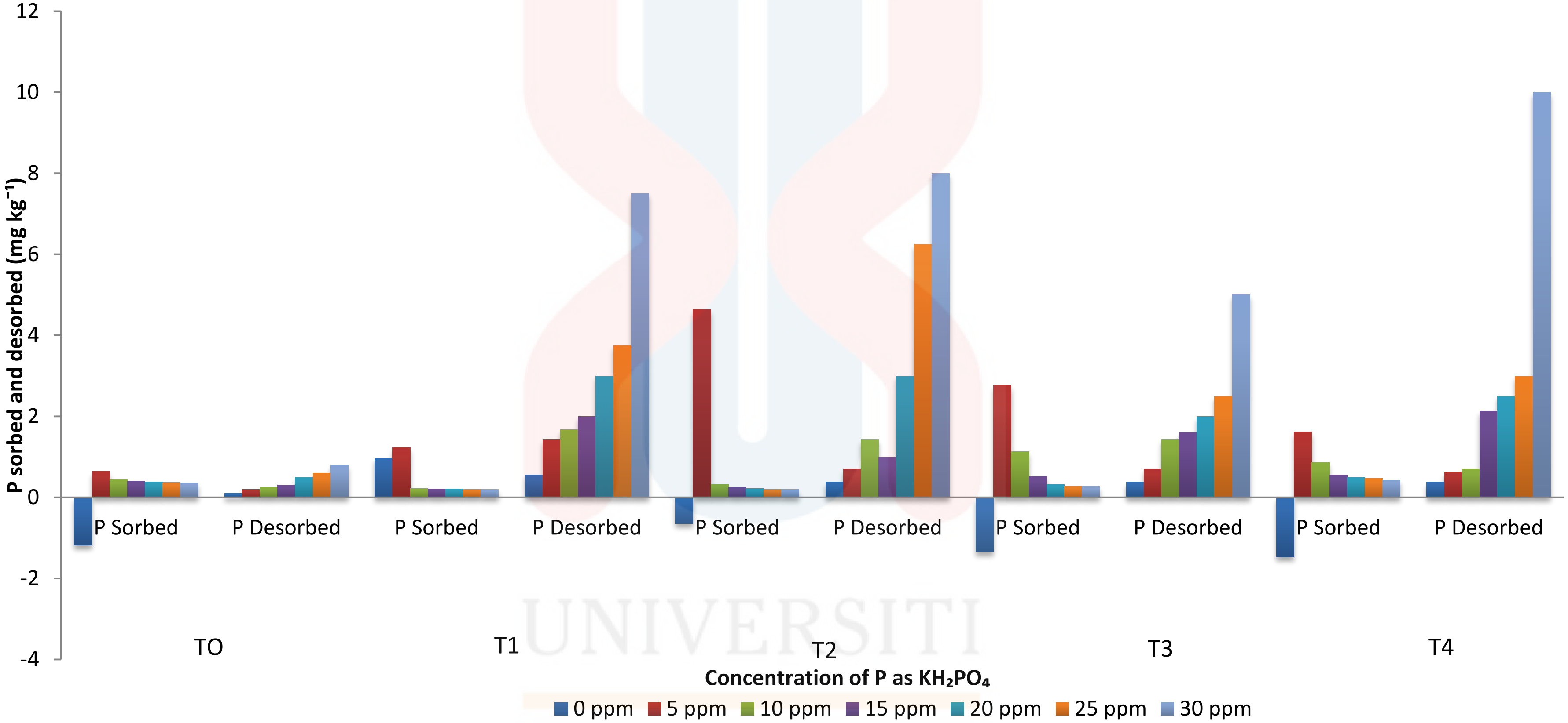

Figure 4.2: Effects of treatments on the amount of P sorbed and desorbed

4.3 Compost Buffering Capacity

The response of rice straw compost to acid addition was fit with linear regression function (Figure 4.3).The Figure 4.3 shows that rice straw compost had high compost buffering capacity. High pH buffering capacity in compost can help to ensure the stability in soil pH (Nelson & Su, 2010). This ability can prevent drastic change of soil pH that might be unfavourable for plant growth and microorganisms. Well buffered soil can stimulated from the well buffered compost. According to Ch'ng, Ahmed and Ab. Majid (2016), the high buffering capacity can be observed in the soil that amended with organic amendments.

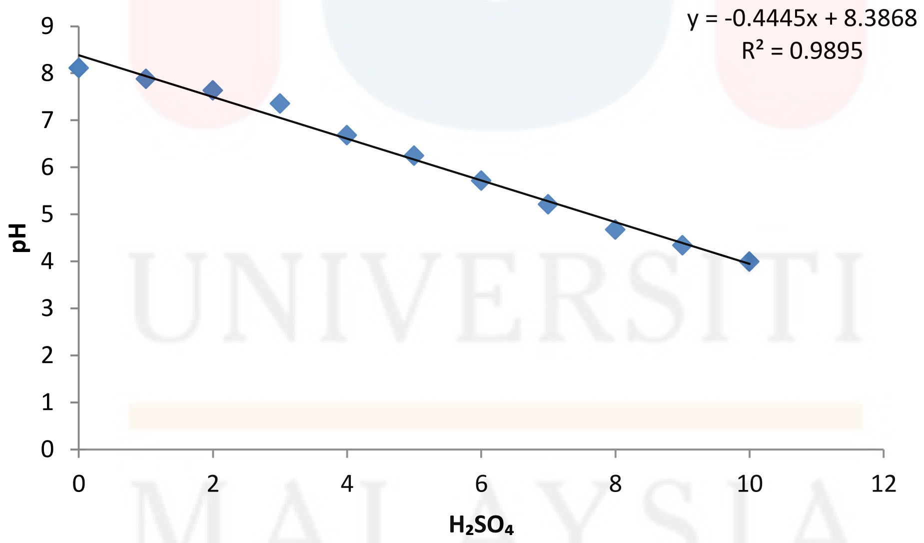

Figure 4.3: Compost buffering capacity of rice straw compost

This study shows that organic amendments (rice straw compost) had high cation exchange capacity (CEC). Therefore, that compost can help to increase the soil buffering capacity, more reserved and reduced exchangeable acidity (Latifah, Ahmed, Muhamad, & Majid, 2018). In addition, that compost can produce various organic acid and solubilize of basic cation (Mg, K and Ca) if added with soil. Acidic soil with compost significantly increase the soil pH and soil EC because organic matter had large amount of negative charge which can give strong reaction with basic organic molecules (Latifah, Ahmed, Muhamad, & Majid, 2017). Consequently, the negatively charge of rice straw compost were absorbed the rapid proton (H^+) ions in acidic soil (Sanusi, Ch'ng, & Othman, 2018) because high H^+ concentrations can affect mineral content in soil, dissolved cations break crystal lattice apart, and leading to mineral degradation. In other words, the depletion in exchangeable acidity, Al and Fe was associated to the increase in soil pH (Ch’ng et al., 2016), the process that could increase the P availability in soil due to decreased of Al and Fe concentration. Under low pH of soil condition, fungi are relatively favoured which can affect organic matter to decompose. The rice straw compost has weakly acidic functional groups on its organic molecule and that functional group can favour organic matter as an effective buffer in soil (Latifah et al., 2018).

The high pH buffering capacity cause by organic amendment (rice straw compost) is very significant for the P availability (Ch’ng et al., 2016) in Ultisol and Oxisols soil in tropics. High weathered soil is nature devoid from basic cation. These nature characteristic caused them low in productivity (Shamshuddin & Daud, 2010) because of nutrient leaching and the accumulation of sesquioxides (Anda et al., 2008). In addition, low in nutrient cause pH decline which indicates to P fixation in soil due to active forms at Al ad Fe oxides. Besides, the higher Al concentration can give risk of Al toxicity for plant roots. High pH rice straw compost can used to buffer soil pH as well as increase availability of P in acid soil. The application of compost with higher in C:P ratios (Table 4.2) can enhance P desorption in soil. The enhanced P desorption from compost P influenced the nutrient availability because the soil can hold more nutrients, thereby reduce the losses of P. On the other hand, the P availability in soil will increase and ready as nutrient for plant uptake.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

The effect of rice straw compost on P sorption and desorption were studied and calculated using Langmuir Equation. The P sorbed decreased with an increase of P concentration in the equilibrium solution (>10 mg L^{-1}) but P desorption showed reverse reactions. The P desorption increased in the sequence of T0<T1<T2<T3<T4 with increasing P application rates (10 to 30 mg L^{-1}). The decrease in P sorption was more pronounced at the higher compost application rate compared to lower compost application due to low binding energy of compost. Apart from that, rice straw compost had the role of increasing pH and CEC in soil due to higher pH buffering capacity of compost. Higher CEC was associated with compost surfaces which has characterized by negative charged functional group which favours to adsorb cations instead of anions such as orthophosphate, PO_4^{3-} the only form that available for plant uptake. In other words, applying the compost to the soil have greater tendency to reduce the exchangeable Al and Fe thus increased the P desorption in soil. High pH buffering seem to be importance in increasing the available P content in soil that can use for plant uptake. For future recommendation, sorption and desorption study can be evaluated using different type of compost or organic amendment in a research because it is easy to compare which organic amendment has high potential in reducing P fixation in soil.

REFERENCES

Anda, M., Shamshuddin, J., Fauziah, C.I & Syed Omar, S.R. (2008a). Mineralogy and factor controlling charge development of three Oxisols developed from different parentmaterials. *Geoderma, 143,* 153-167.

Bai, J., Ye, X., Jia, J., Zhang, G., Zhao, Q., Cui, B., & Liu, X. (2017). Phosphorus sorption-desorption and effects of temperature, pH and salinity on phosphorus sorption in marsh soils from coastal wetlands with different flooding conditions. *Chemosphere*, *188*, 677–688. https://doi.org/10.1016/j.chemosphere.2017.08.117

Bouyoucos, G. J. (1962) Hydrometer meter improved for making particle size analysis of soils. *Agron J* 54: 464−465.

Bremner, J. M. 1965. Total nitrogen. In Method of soil analysis, Part 2, ed. C. A. Black, D. D. Evans, L. E. Ensminger, J.L. White, F. E. Clark and R. C. Dinauer, 1149–78. Madison, WI: American Society of Agronomy.

Ch'ng, H. Y., Ahmed, O. H., Kassim, S., Muhamad, N., & Majid, A. (2013). Co-composting of pineapple leaves and chicken manure slurry, 1–8.

Ch’ng, H. Y., Ahmed, O. H., & Majid, N. M. A. (2016). Minimizing phosphorus sorption and leaching in a tropical acid soil using Egypt rock phosphate with organic amendments. *Philippine Agricultural Scientist*, *99*(2), 176–185. https://doi.org/10.15413/ajar.2015.0151

Ch'ng, H., Y. (2018). Effects of incubation period and Christmas Island rock phosphate with different rate of rice straw compost on phosphorus availability in acid soil, (November). https://doi.org/10.3934/agrfood.2018.4.384

College of Tropical Agriculture and Human Resources [CTAHR], (2017). A Soil Phosphorus Primer for Hawaiian Soils.Retrieved from https://www.ctahr.hawaii.edu/oc/freepubs/pdf/SCM-33.pdf

Cottenie, A. (1980). Soil testing and plant testing as a basis of fertilizer recommendation. FAO *Soils Bul* 38: 70−73.

Cuevas, V. C., Orajay, J. I., & Lagman, C. J. A. (2014). Rice Straw Compost as Amendment to Reduce Soil Copper Toxicity in Lowland Rice Paddy Field. *Philippine Science Letters*, *7*(2), 350–355.

Dan, W., Nianpeng, H., Qing, W., Yuliang, L., Qiufeng, W., Zhiwei, X., & Jianxing, Z. (2016). Effects of Temperature and Moisture on Soil Organic Matter Decomposition Along Elevation Gradients on the Changbai Mountains, Northeast China. *Pedosphere*, *26*(3), 399–407. https://doi.org/10.1016/S1002-0160(15)60052-2

Dixon, R. K. & Wisniewski, J. (1995). Global forest systems: an uncertain response to atmospheric pollutants and global climate change. Water Air Soil Pollution 85, pp. 101-110.

Duong, T., T., T. (2013), Compost effects on soil properties and plant growth. Thesis (PHD). University of Adelaide, School of Agriculture, Food and Wine, Australia

Essington, M., E. (2004). Soil and Water Chemistry : An integrative Approach. Taylor & Francis, Abingdon-on-Thames

Fink, J. R., Inda, A. V., Bavaresco, J., Barrón, V., Torrent, J., & Bayer, C. (2016). Adsorption and desorption of phosphorus in subtropical soils as affected by management system and mineralogy. *Soil and Tillage Research*, *155*, 62–68. https://doi.org/10.1016/j.still.2015.07.017

Fortune, S., Lu, J., Addiscott, T., & Brookes, P. (2005). Assessment of phosphorus leaching losses from arable land. *Plant And Soil*, *269*(1-2), 99-108. doi: 10.1007/s11104-004-1659-4

Füleky, György and Benedek, S. (2010). Chapter 12: Composting to recycle biowaste. Sociology, Organic Farming, Climate Change and Soil Science, 77-107

Garland, G., Bünemann, E. K., Oberson, A., Frossard, E., Snapp, S., Chikowo, R., & Six, J. (2018). Phosphorus cycling within soil aggregate fractions of a highly weathered tropical soil : A conceptual model. *Soil Biology and Biochemistry*, *116*(June 2017), 91–98. https://doi.org/10.1016/j.soilbio.2017.10.007

Guppy, C. N., Menzies, N. W., Moody, P. W. and Blamey, F. P. C. (2005). Competitive sorption reactions between phosphorus and organic matter in soil: A review. Soil Research 43 (2): 189-202

Haynes RJ, Mokolobate MS (2001). Amelioration of Al toxicity and P deficiency in acid soils by additions of organic residues: a critical review of the phenomenon and the mechanism involved. Nutr. Cycl. Agroecosyst. 59(1): 47-63.

Jamal, K., Kamarulzaman, N. H., Abdullah, A. M., Ismail, M. M., & Hashim, M. (2014). Adoption of Fragrant Rice Farming: The Case of Paddy Farmers in the East Coast Malaysia. *UMK Procedia*, *1*(October 2013), 8–17. https://doi.org/10.1016/j.umkpro.2014.07.002

Khan, M. S., Zaidi, A., Ahemad, M., Oves, M. and Wani, P. A. (2010). Plant growth promotion by phosphate solubilizing fungi – current perspective. Arch Agron Soil Sci. 56 :73-98

Latifah, O., Ahmed, O. H., Muhamad, N., & Majid, A. (2017). Enhancing nutrients use efficiency and grain yield of zea mays l . Cultivated on a tropical acid soil using paddy husk compost and clinoptilolite zeolite Geoderma Enhancing nitrogen availability from urea using clinoptilolite zeolite. *Geoderma*, *306*(June), 152–159. https://doi.org/10.1016/j.geoderma.2017.07.012

Latifah, O., Ahmed, O. H., Muhamad, N., & Majid, A. (2018). Soil pH Buffering Capacity and Nitrogen Availability Following Compost Application in a Tropical Acid Soil, *2397*. https://doi.org/10.1080/1065657X.2017.1329039

Nelson, P. N., and N. Su. 2010. Soil pH buffering capacity: A descriptive function and its application to some acidic tropical soils. Australian Journal of Soil Research 48:201–07.

Mahimairaja, S., Bolan, N., S. and Hedley, M. J. (1994). Dissolution of phosphate rock during the composting of poultry manure: An incubation experiment. Fertilizer Research 40 (2):93-104

Malik, M., A., Marschner, P. and Khan, S., K. (2012). Addition of organic and inorganic P sources to soil- Effects on P pools and microorganisms. Soil biology and Biochemistry 49 (0):106-113

Maskina MS, Randhawa NS, Sinha MK (1980) Relation of growth and zinc uptake of rice to quantity, intensity and buffering capacity factors of zinc in soils. Plant Soil 54:195–205

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

Murphy, J., Riley, J. P. (1962). A modified single solution method for the determination of phosphate in natural waters. *Anal Chim Act* 27: 31−36.

Mukherjee A, Zimmerman AR, Harris W (2011). Surface chemistry vari-ations among a series of laboratory-produced biochars. Geoderma. 163: 247–255.

Nwoke, O. C., Vanlauwe, B., Diels, J., Sanginga, N., Osonubi, O. & Merckx, R. (2003). Assessment of labile phosphorus fractions and adsorption characteristics in relation to soil properties of West African savanna soils. Agriculture, Ecosystems & Environment, 100(2-3), 285-294.

Nziguheba, G., Palm, C. A., Buresh, R. J., & Smithson, P. C. (1998). Soil phosphorus fractions and adsortion as affected by organic and inorganic sources. *Plant and Soil*, *198*, 159–168. https://doi.org/10.1023/A:1004389704235

Pagliari, P. H., Kaiser, D. E., Rosen, C. J., & Lamb, J. A. (2009). The nature of phosphorus in soils. *University of Minnesota*, *July*(Revised), 1–5.

Park, J., Lee, Y., Ryu, C., Park, Y. K. (2014). Slow pyrolysis of rice straw: Analysis of products properties, carbon and energy yields. Bioresource Technology 155, 63-70.

Plaster, E. (2003). Soil science & management. Clifton Park, NY: Thomson Delmar Learning.

Peech, H. M. (1965) *Hydrogen-ion activity*. In: Methods of soil analysis, part 2, C.A. Black, D.D. Evans, L.E. Ensminger, J.L. White, F.E Clark, R.C. Dinauer. Madison, WI: Am Soc Agron

Rajamoorthy, Y., Rahim, K. b A., & Munusamy, S. (2015). Rice Industry in Malaysia: Challenges, Policies and Implications. *Procedia Economics and Finance*, *31*(15), 861–867. https://doi.org/10.1016/S2212-5671(15)01183-1

Rosmiza, M. Z., Davies, W. P., Aznie, C. R. R., Mazdi, M., & Jabil, M. J. (2014). Farmers' knowledge on potential uses of rice straw: an assessment in MADA and Sekinchan, Malaysia. *Geografia. Malaysian Journal of Society and Space*, *10*(5), 30–43.

Rowell DL (1994) *Soil science,* methods and applications. Longman Group UK Limited, 86−87.

Sanusi, S., Ch'ng, H. Y., & Othman, S. (2018). Effects of incubation period and Christmas Island rock phosphate with different rate of rice straw compost on phosphorus availability in acid soil, *3*(October), 384–396. https://doi.org/10.3934/agrfood.2018.4.384

Schjønning, P., Mcbride, R. A., Keller, T., & Obour, P. B. (2017). Geoderma Predicting soil particle density from clay and soil organic matter contents, *286*, 83–87. Retrieved from http://www.fao.org/giews/countrybrief/country/MYS/pdf/MYS.pdf

Shafie, S. M. (2015). Paddy residue based power generation in malaysia: Environmental assessment using LCA approach. *ARPN Journal of Engineering and Applied Sciences*, *10*(15), 6643–6648.

Shafie, S. M., Masjuki, H. H., & Mahlia, T. M. I. (2014). Life cycle assessment of rice straw-based power generation in Malaysia. *Energy*, *70*, 401–410. https://doi.org/10.1016/j.energy.2014.04.014

Shamshuddin, J., & Daud, N. W. (2010). Classification and Management of Highly Weathered Soils in Malaysia for Production of Plantation Crops.

Shirvani, M., Shariatmadari, H., & Kalbasi, M. (2005). Phosphorus buffering capacity indices as related to soil properties and plant uptake. *Journal of Plant Nutrition*, *28*(3), 537–550. https://doi.org/10.1081/PLN-200049235

Silva, J.A. 2000. Inorganic fertilizer materials. In Silva, J.A., and R.S. Uchida (eds.) Plant Nutrient Management in Hawaii's Soils: Approaches for Tropical and Subtropical Agriculture, pp. 117-120. College of Tropical Agriculture and Human Resources: Honolulu, HI.

Simonsson, M., Östlund, A., Renfjäll, L., Sigtryggsson, C., Börjesson, G., & Kätterer, T. (2018). Pools and solubility of soil phosphorus as affected by liming in long-term agricultural field experiments. *Geoderma*, *315*(December 2017), 208–219. https://doi.org/10.1016/j.geoderma.2017.11.019

Tahir, S., & Marschner, P. (2017). Clay Addition to Sandy Soil—Influence of Clay Type and Size on Nutrient Availability in Sandy Soils Amended with Residues Differing in C/N ratio. *Pedosphere*, *27*(2), 293–305. https://doi.org/10.1016/S1002-0160(17)60317-5

Tan, K. H. 2005. Soil sampling, preparation, and analysis. 2nded. Boca Raton, FL: CRC Press.

Tiessen, H. (2011). Phosphorus Availability in the Environment. In: eLS. John Wiley & SonsLtd,Chichester.http://www.els.net[doi:10.1002/9780470015902.a0003188.pub2]

Trazzi, P. A., Leahy, J. J., Hayes, M. H. B., & Kwapinski, W. (2016). Adsorption and desorption of phosphate on biochars. *Journal of Environmental Chemical Engineering*, *4*(1), 37–46. https://doi.org/10.1016/j.jece.2015.11.005

United States Department of Agriculture [USDA]. (2018). Soil Phosphorus. Retrieved April 9, 2018 from website https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_053254.pdf

Wang, L., & Liang, T. (2014). Effects of exogenous rare earth elements on phosphorus adsorption and desorption in different types of soils. *Chemosphere*, *103*, 148–155. https://doi.org/10.1016/j.chemosphere.2013.11.050

Weindorf, D. C., James, P. M. and Cesáreo L. S. (2011). Organic compost and manufactured fertilizers: Economy and Ecology. Integrating agriculture, conservation and ecotourism : Examples from the field, issues in agroecology-Present status and future prospectus 1, 1-27

Xu, Z., Yu, G., Zhang, X., Ge, J., He, N., Wang, Q., & Wang, D. (2015). The variations in soil microbial communities , enzyme activities and their relationships with soil organic matter decomposition along the northern slope of Changbai Mountain, *86*, 19–29.

Zhang, L., Hong, S., He, J., Gan, F., & Ho, Y.-S. (2011). Adsorption characteristic studies of phosphorus onto laterite. *Desalination and Water Treatment*, *25*(1–3), 98–105. https://doi.org/10.5004/dwt.2011.1871

Zheng, S. J. (2010). Crop production on acidic soils : overcoming aluminium toxicity and phosphorus deficiency, 183–184. https://doi.org/10.1093/aob/mcq134

Zhou, M., and Y. Li. 2001. Phosphorus-sorption characteristics of calcareous soils and limestone from the southern everglades and adjacent farmlands. Soil Science Society of America Journal 65:1404-1412.48

APPENDICES

Figure 1: Rice straw compost

Figure 2: Soil pH determination

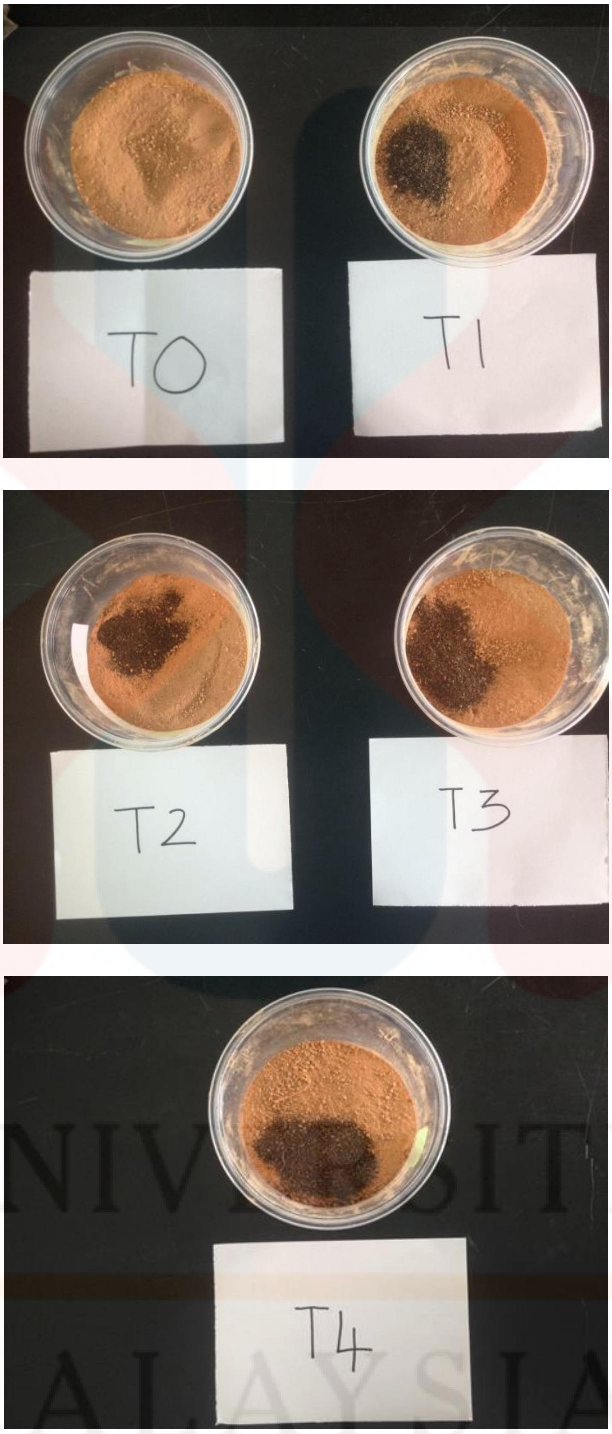

Figure 3: Soil treatment (T0,T1,T2,T3 and T4)

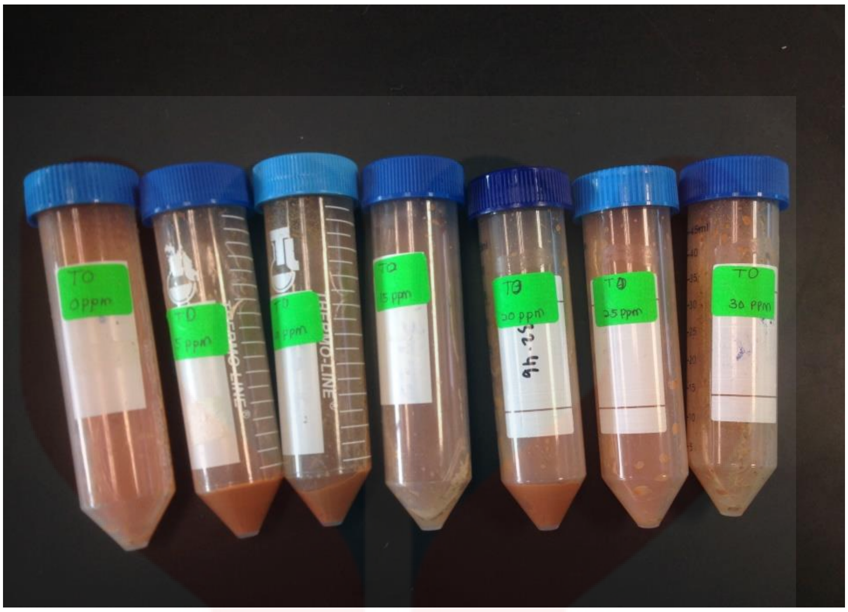

Figure 4: Soil with Different Concentration KH_2PO_4

Figure 5: The Soil for Desorption Study after Centrifuge