Assessing Soil Phosphorus Availability and Dry Matter Production of Choy Sum (*Brassica chinensis* var. *parachinensis*) on a Tropical Acid Soil By using Rice Husk Biochar

Ainnatul Hakimah Bt Azhar

F16A0012

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DECLARATION

I hereby declare that the work embodied in here is the result of my own research except for the excerpt as cited in the references.

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Signature

Student's Name : Ainnatul Hakimah Bt Azhar

Matric No : F16A0012

Date :

Verified by :

____

Supervisor Signature

Supervisor's Name : Dr. Huck Ch'ng Ywih

Stamp :

Date :

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Menilai Ketersediaan Fosforus Tanah dan Pengeluaran Kering Choy Sum (*Brassica chinensis* var. *parachinensis*) ke atas Tanah Asid Tropika dengan Menggunakan Biochar Sekam Padi

ABSTRAK

Fosforus (P) adalah makronutrien penting untuk pertumbuhan dan pembangunan tumbuhan. Walau bagaimanapun, kekurangan fosforus di tanah asid tropika adalah masalah lazim kerana fosforus tidak organic larut terikat dengan aluminium dan besi. Penggunaan pindaan biochar boleh digunakan untuk mengurangkan pengikatan fosforus dalam tanah asid dengan mengurangkan ketersediaan aluminium dan besi di tanah ini. Oleh itu, objektif kajian ini adalah untuk (i) mencirikan sifat fizikokimia yang terpilih dalam sampla tanah, (ii) menentukan ketersediaan fosforus yang tersedia ada,(iii) menilai parameter pertumbuhan terpilih dari *Brassica chinensis* var. *parachinensis* (panjang tanaman, jumlah daun, panjang akar, berat kering pucuk dan akar) apabila meminda baja kimia dengan biochar sekam padi komersil. Percubaan pasu dilakukan selama 30 hari dan *Brassica chinensis* var. *parachinensis* digunakan sebagai tanaman ujian. Sample tanah kemudian dikumpulkan dan dianalisis pada akhir percubaan pasu. Biochar sekam padi meningkatkan pH tanah dengan ketara berbanding biochar yang tidak dipinda. Selain itu, biochar sekam padi juga ketara menggurangkan keasidan boleh tukar dengan aluminium dan besi. Hasilnya, ketersediaan fosforus meningkat di dalam tanah kerana berikutan afiniti tinggi biochar terhadap aluminium dan besi yang menyebabkan penyerapan fosforus tidak organik yang efisien dalam meningkatkan pengambilan nutrien fosforus yang tersedia. Hasil keputusan juga menunjukkan peningkatan fosforus dalam tanah meningkatkan pengeluaran bahan kering *chinensis*. Aplikasi biochar ke tanah boleh digunakan untuk meningkatkan produktiviti *chinensis* pada tanah asid dengan meningkatkan ketersediaan fosforus dengan meningkatkan ketersediaan fosforus melalui penurunan kepekatan besi di dalam tanah.

Kata kunci: *Pengikatan fosforus, biochar sekam padi, besi, ketersediaan fosforus, pengeluaran bahan kering*

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ABSTRACT

Phosphorus (P) is an important macronutrient for plant growth and development. However, phosphorus deficiency in tropical acid soils is a common problem because soluble inorganic phosphorus is fixed by iron. The application of biochar amendments could be used to mitigate phosphorus fixation in acid soil by reducing aluminium and iron availability in these soil. Thus, the objectives of this study were to (1) characterized the selected physico-chemical properties of soil samples, (ii) determine the soil phosphorus availability (iii) assess the selected plant growth parameters of *Brassica chinensis* var. *parachinensis* (plant length, number of leaves, root length, dry weight shoot and root) upon amending chemical fertiliser with commercial rice husk biochar. A pot trial was conducted for 30 days and *chinensis* was used as a test crop. The soil samples were then collected and analysed at the end of pot trial. Rice husk biochar significantly increased soil pH compared with non-amended biochar. Additionally, rice husk biochar also significantly declined exchangeable acidity and exchangeable of aluminium and iron. As a result, phosphorus availability increased within the soil due to high affinity of biochar towards aluminium and iron drive efficient of inorganic P absorption which causing an increased in available P nutrients uptake. The results also showed that increasing the availability of phosphorus in soil, improved the dry matter production of *chinensis* through declining the aluminium and iron concentration within the soil.

Keywords: *Phosphorus fixation, rice husk biochar, iron, phosphorus availability, dry matter production*

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LIST OF ABBREVATION AND SYMBOLS

AAS	Atomic Absorption Spectrophometer
Al	Aluminium
ANOVA	Analysis of Variance
B	Borom
C	Carbon
Ca	Calcium
CEC	Cation Exchange Capacity
CRD	Completely Randomized Design
CIRP	Christmas Island Rock Phosphate
Cu	Copper
DAP	Days after planting
DAS	Days after sowing
EC	Electrical Conductivity
Fe	Iron
HCl	Hydrochloric Acid
HNO_3	Nitric Acid
K	Potassium
KCl	Potassium Chloride
Mg	Magnesium
MOP	Muriate of Potash
N	Nitrogen
Na	Sodium

NaOH	Sodium Hydroxide
OM	Organic Matter
OH	Hydroxide
P	Phosphorus
pH	Potential of Hydrogen
Ppm	Parts per million
SOM	Soil Organic Matter
SPSS	Statistical Package for Social Science
TC	Total Carbon
USDA	United States of Department of Agriculture
UV	Ultraviolet
Zn	Zinc

CHAPTER 1

INTRODUCTION

1.1 Research Background

Malaysian soils dominantly (about 70%) fall into the Ultisol and Oxisol Orders in Soil Taxonomy (Sung *et al.*, 2017). Generally, soil of Malaysia is categorized as highly weathered tropical soil, less fertile, low nutrients availability and acidic. Soil acidification may occur in natural process and has referred as a form of chemical degradation of the soil (Sung *et al.*, 2017). Acidic soil is classified as soil that has pH value below than 7 which ranging from 4 to 5. It is characterized as problematic soil that have natural characteristic which limiting the crop growth and development, thus requires special management practices for crop production. Most of the tropics soil are poor of nutrients as well as minerals availability where it is vital for crops growth and development especially Phosphorus due to Phosphorus fixation.

These types of soils are acidic in nature way, explains the status and the effective Cation Exchange Capacity (CEC) of Malaysian soil. The acidic soil occur due to high weathering and rainfall that leads to the losses of base cations (Ch'ng *et al.*, 2014). A very low basic cation status and effective CEC contribute to soil degradation which causes severe reactions such as increasing toxic levels of Fe^{2+} and Al^{3+}. This significantly drives the soil become reduce the CEC, escalate the anion exchange capacity and promote the loss of basic cations that results into limited of nutrients availability within the soil.

Phosphorus (P) is generally the fourth most abundant nutrient in plant tissue. Phosphorus is very essential in early stages of growth and germinating plants seedling. It is absorbed by plants as a source or a part component of genetic material such as nucleic acids, membranes, DNA and RNA and is involved in cell membrane function and integrity. Phosphorus also a component of chemical adenosine triphosphate (ATP) and adenosine diphosphate (ADP) system, which store and transfer energy (Osman, 2013).

Plants absorbed available P within soil in the form of organic P, where the process of immobilization occurs by converting inorganic P into organic P. These processes are important as they aid plants to promote early and rapid growth, helps roots of young plants to develop, improves water uptake efficiently by roots and speed up crop maturity, improves grains and fruit quality, and improves N uptake efficiency in plants. Consequently, the crop able to grow vigourly and healthier under sufficient of P and later may able to have high production.

Phosphorus (P) is one of vital macronutrients for crop growth (Ch'ng *et al.*, 2015). Phosphorus is available to plants in soils generally occurs at pH of between slightly acidic to neutral, indicates 6 – 7. Below than this range, the P is fixed due to numerous and active forms of Fe and Al within soils. However, a higher pH (<7) results in low P availability due to precipitation with Ca. Acidic soil contains Phosphorus (P) that mainly available in two forms; primary orthophosphate ion ($H_2PO_4^-$) and secondary orthophosphate ion (HPO_4^{2-}) (United States of Department, 2014).

Phosphorus is highly shortage due to fixation which usually occurs in soil high saturated with active forms of Fe and Al oxide and hydroxide. Phosphorus deficiency in most acid soils due soluble inorganic P fixed with Al and Fe (Ch'ng *et al.,* 2014). The reaction between soluble P ions with Fe as well as Al contributes to less availability of P (Ch'ng *et al*., 2014), due the formation of insoluble phosphate (Bryan & Jason, 2005). Fe and Al has high affinity for P causes the immobilization of P and restrains freely P ions in the problematic soil. As a result, P availability in soil decreased and lowers the nutrient P uptake by crop.

Since the less availability of P increasing gradually, it drives the farmers' intention to apply conventional practices in order to mitigate phosphate fixation within acid soil. Liming and regular application of P fertilizers are commonly used as a practices to alleviate P fixation and provide an adequate supply of plant-available P. Liming helps to maintain the P availability by reducing the Fe and Al ions solubility for fixed with P within soils (Ch'ng *et al*,. 2014). However, the excessive or over-liming will severe another problem which restrains the P availability due to form a precipitate compound with Ca that is not available for plants uptake.

Regular application of P fertilizer able contributes to the excessive and unbalanced usage to the soil. The exaggerated application amount of fertilization will cause the accumulation of excessive fertilizer within the farm land. A high rainfall in tropical region later aids the accumulation of P fertilizer to leach below root zone and reach water bodies or courses. Nutrient leaching is the downward movement of dissolved nutrients in the soil profile with percolating water (Lehmann & Schroth, 2003). It may result eutrophication which can cause algae blooms which are toxic. Eutrophics lakes usually appear in alkaline conditions (7 – 11). In this case, it will cause detrimental effects on aquatic organisms' life due to polluted water bodies.

Malaysian soil typically contains iron (Fe) oxides and hydroxide in abundance amounts. The presence and availability of these Fe is depends on the conditions of climate of regions which could influence the soil evolution or soil weathering. Fe is an acidic cations, metal ions and particularly adsorbed soluble inorganic phosphate by functional groups in order to form thermodynamically stable complexes (Bortoluzzi *et al*., 2015; Fink *et al*., 2016b) or forming into biological active organic compounds remains as organic P in soil (immobilize the P uptake by plants) (Conte *et al*., 2002; Martinazzo *et al*., 2007; Dodd; Sharpley, 2015). The high affinity of Fe for P proceed the immobilization of P ions from become freely and ready-available form for crop uptake. The amount of Fe present in soil influenced the P remains in soil solution by extent to which it is adsorbed and desorbed. Most tropical soils are low in available P due to strong P adsorption site on soil minerals.

Rice becomes the most preferable staple food to Asia population including Malaysia. In Malaysia, Norimah *et al*. (2008), reported that are about $2\frac{1}{2}$ plates of rice per day consumed among the adult as the consumption pattern of rice, indicates a large number of production require in order to achieve and meet with local demand. However, it was found that the rice production has indirectly contribute to large number of paddy residue neither rice husks nor rice straw in the production of rice. Malaysia has used an incentive method to eliminate the paddy residue through a conventional practice which is open burning. This approach is not environmentally friendly as it will cause harm to human health as well as pollutes the environments.

In this case, the paddy residues are utilized and converted into several by-products. For instance, converting the rice husk residue into biochar make it profitable or marketable products. It is creates, and adding value to the rice husk waste turning into biochar, while able to manage the agricultural waste. Biochar can be referred as a carbonaceous product produced as soil additive for agricultural and environmental management (Guo & Rockstraw, 2007). It is classified as organic planting material and could act as similar as organic amendments; categorized as plant-based able to improve conditions for growing vegetables especially in terms of soil structure.

It is added to the soil due to their ability to improve soil fertility, plant growth, soil water retention, soil carbon sequestration, and soil properties (physical, chemical, and biological). Another researcher mentioned, biochar enhances soil porosity, soil structure, soil water holding capacity as well as soil erosion control (Tomasz *et al.*, 2017). Biochar can be applied to enhance the chemical soil properties and alleviate the P fixation. The biochar has high affinity for Fe, thus P can move as freely ions in soil solution and ready-available for crop uptake. It increases beneficial soil microorganisms, soil organic matter, and improve moisture retention. Besides, rice husk biochar has high cation exchange capacity (CEC) as well as increasing P absorption. The biochar of rice husks could be used to minimize the amount fertilizer requirements and environmental effects associated with overuse of fertilizers.

1.2 Problem Statement

The excessive present of Al and Fe within the tropical soil contribute to the P fixation. It drives the farmers' intention to regular apply P fertilizer for better crop yield. However, a regular or excessive application can leads to the detrimental effects on the environments as well as human health. Therefore, the current revealed aims to assess the effects pf the application of commercial rice husk biochar on soil P availability and selected plant growth parameters of *Brassica chinensis* var. *parachinensis* on the tropical acid soil of Malaysia.

1.3 Research Question

If the acid soil contains less nutrients availability and resulting poor on selected plant growth parameters, can it be solved through application commercial rice husk by providing the nutrients more readily to be uptake by plant in enhancing the plant growth? If the acid soil with lessen P available for the plant uptake due to fixation Fe, can it be solved through application of commercial rice husks with higher affinity of Fe by releasing P ions freely in soil solution for plant uptake?

1.4 Objectives

The objectives of this study were to:

1. Characterize the selected proximate and ultimate analysis of the soil samples.
2. Determine the soil P availability of *Brassica chinensis* var. *parachinensis* upon amending chemical fertiliser with commercial rice husk biochar.
3. Assess the selected plant growth parameters of *Brassica chinensis* var. *parachinensis* (plant length, number of leaves, root length, dry weight shoot and root) upon amending chemical fertiliser with commercial rice husk biochar.

1.5 Scope of study

The study focused on sustainable practices to increase the shortage of mineral P availability in problematic soil and to enhance the plant growth performance and within *Brassica chinensis* var. *parachinensis.* cultivated on a tropical acid soil using commercial rice husk biochar.

1.6 Significance of study

This study aimed on the commercial rice husk biochar inputs to the acid soils in Malaysia by helping the farmers to use sustainable management technique compared to conventional practices. Prevent the over-liming and regular application P fertilizer (leads to excessive and unbalanced) later interfere soil and water ecosystem by improving the P availability through application commercialized rice husk biochar. In addition, the useful of commercialized rice husk is environmental friendly and economical (inexpensive) while utilized the agricultural waste for better crop performance.

1.7 Hypothesis

H_0: The application of commercial rice husk biochar will not exert positive impact on the soil P availability and selected plant growth parameters of *Brassica chinensis* var. *parachinensis* (plant length, number of leaves, root length, dry weight shoot and root) of *Brassica chinensis* var. *parachinensis* on the tropical acid soils.

H_A: The application of commercial rice husk biochar will exert a positive impact on the soil P availability and selected plant growth parameters of *Brassica chinensis* var. *parachinensis* (plant length, number of leaves, root length, dry weight shoot and root) of *Brassica chinensis* var. *parachinensis* on the tropical acid soils

CHAPTER 2

LITERATURE REVIEW

2.1 Soil acidification

Soil acidification is defined the soil pH below than 7 where occur naturally in highly weathered and rainfall regions. The acidification of soil typically present in the most of tropical and humid regions. Acidic soil usually characterized by having poor fertility, low nutrient holding capacity, and yet to result in producing low productivity and yield of agricultural crops. As previously studied, most of tropical is acidic, less fertile, and poor nutrients availability especially in phosphorus elements due to Phosphate fixation process (Ch'ng *et al.*, 2014).

Metal cations ions such as Fe and Al mainly causing the acidic form of soil condition. Rising concentration of Fe and Al due to weathering process tends to come out of soil solution and forms into compounds which remain in the soils. Continuous accumulation of both cations leads to high level where it becomes toxicity to the plants. The freely of both ions release during the weathering make them more accessible on the cation exchange sites whether in solution or on the exposed surface compare to other base cation.

2.1.1 Nutrient availability in acid soil

Soils usually carry a negatively charges on the particles surfaces. These particles surface used to attract and hold base cations, positively charged such as Calcium, Potassium, Sodium, and others. However, the soil particles surfaces are more strongly attract and hold the hydrogen ions compared than other base cations. Any acidification reactions can cause the hydrogen ions concentration in the soil increasing and initially leads the hydrogen ions to replace the site vacated by base ions on the soil particles surface. It reduces the nutrients retention or nutrients holding capacity which later become susceptible to leaching out of the soil and inadequate nutrients for plants uptake.

Most tropical or humid regions consist of highly rainfall, excessive of water moving through the soil carry the other base ions such as Ca and Mg. Calcium typically important in balancing the negatively charge of soluble anions. The losses of Ca in soil can decline the pH and thus significantly turn the soil become acidic. Hydrogen ions concentration increased at the mineral structure drives the releasing of Fe and Al as well as other base cations contains in the mineral structure. When the ions of Fe and Al come out from the soil solution and eventually form hydrous oxides and remains within the soils. Thus, leads to the inadequate source of nutrients availability of Fe and Al in soluble form for the nutrients uptake.

2.1.2 Iron toxicity in acid soil

Generally iron (Fe) is the fourth most abundant element on earth (Schulte, n.d). It usually found in the form of silicate minerals or iron oxides and iron hydroxides, which cannot be absorb for plant use (Schulte, 1992). Iron is abundance in the acidic soil and typically decreases sharply when the soil solution pH is increases with a minimum around 7.4 - 8.5 (Schulte, 1992). Iron deficiency is extremely rare in tropical regions (Ch'ng *et al*., 2015).

Some plants can cope with high iron availability in the soil but some plants have low tolerance or high sensitive to extreme concentrated iron level. Some acid-loving crops or high tolerance with iron availability are alfalfa, corn, small grains (Schulte, 1992). However, the highly weathered cause the accumulation of iron oxide in the unavailable form or in the solid stated which remains in the soil. As a result, Fe ions uptake by plants become decline and effect on their growth performance as well as yield. Rising of accumulation of iron oxide in the acid soil enhance the fall of pH below than 7 and thus, create the excessive of iron availability (Agronomic Library, n.d). The abundance of free of iron ions in the soil solution increases the concentration to levels toxic to many plants. Fe toxicity generally gives detrimental effects on the plant growth towards low tolerance of iron toxicity.

The present of iron oxide in the soil causing another problematic effect whereas tend of P unavailable for the plant uptake. Iron oxide has high affinity for P and thus leads to the limited of P soluble inorganic availability. As stated by Harter (2002), the releasing of Fe during the acidification or weathering process influenced the acidic metal cations become preferentially accessible on cation exchange sites either in solution or on the exposed surface. As the iron oxide ions react with phosphate, they forming as insoluble compound of phosphate that called as P fixation. P is more desired by the Fe ions to bind for and form another insoluble organic compound.

2.2 Phosphorus Cycle in soil

2.2.1 Phosphorus in soil

Phosphorus is one of essential macronutrients (Ch'ng *et al.*, 2015) along with nitrogen (N) and potassium (K) (IFA Country, 2019). It is considered as major nutrients because relatively large amount required by plants and limit of these nutrients consequently affect their growth and development. It is important to maintain the adequate of phosphorus due to crucial role in the plant as well as healthy and increasing the yields. However, Phosphorus typically has a very low solubility and is only available for plant uptake in its inorganic form as HPO_4^{2-} or $H_2PO_4^{-}$ and H_3PO_4 (Schachtman *et al.,* 1998). Phosphorus in soil parent material is found as primarily in mineral forms (Fink *et al.*, 2016). However, the mineral form are involved some actions which later changes the mineral form of P in the soil. These actions involve different factors (parent material, climate, slope, organisms, and time and process (translocation, transformation, addition, and removal) has governed the primary minerals to form a thermodynamic equilibrium (Fink *et al*., 2016).

Usually, the transformation undergoes three processes like physical, chemical, and biological weathering. These transformation process release the dissolved phosphate into the soil solution where it can be absorb or uptake by plant. Another transformation process also lead the formation of Fe and Al into oxides, hydroxides, oxyhydroxides as a result drives to P adsorption due to new functional groups created (Fink *et al.*, 2016). These functional groups are responsible in P fixation and causes the P become unavailable forms in soil solution. As stated by Fink *et al.* (2016) the soil weathering causes the dissolved P from primary mineral to experience some process that alter chemically and biologically of compounds. Precipitation with cations and lead occur during in alkaline soil condition. P also can be adsorbed to the functional groups of Fe and Al oxides and hydroxide in order to form thermodynamically stable complex. In this type of condition typically occur in acidic or problematic soil. The soluble inorganic P also can be formed into biological active compound which immobilizes the P by remaining as organic P in the soil.

The P transformation from mineral forms before organic and inorganic are influenced by some factors affecting its P dynamics in the soil (mineralization and immobilisation) such as microbial activity, moisture, physicochemical and mineralogical soil properties (Santos *et al*., 2008; Shen *et al*., 2011; Tiecher *et al*., 2012).

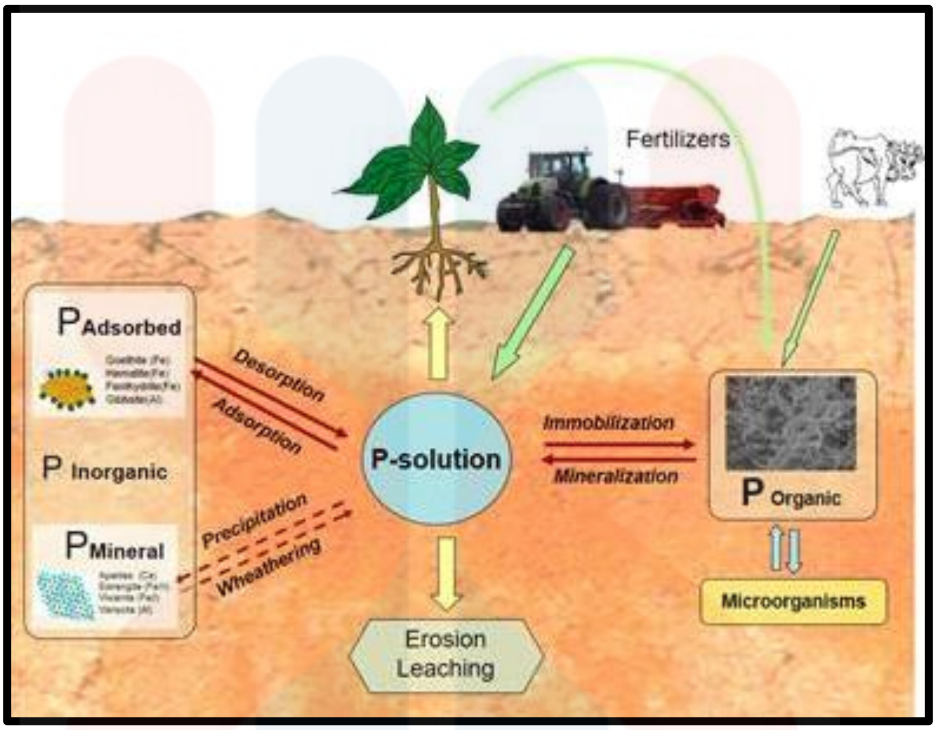

Figure 1 Phosphorus cycle in the soil (Fink *et al*., 2016).

2.2.2 Absorption and Desorption

Absorption and desorption also known as phosphate fixation. Sorption occur during the P in soil solution adhere to a surface of the solid phase such as colloids, while desorption a process releasing the P from the adsorbent surface into soil solution through plant uptake, leaching or runoff (McBride, 2000). In acidic soil, P sorption is governed by the precipitation with acid cations such as Fe and Al which drive to anion exchange capacity between phosphate anions and the elements. The high affinity of Fe and Al bind with P as a result chelate P tightly and causes inhibit plant uptake.

2.2.3 Mineralization

The conversion of organic forms of P to soluble inorganic forms by microorganisms is defined as mineralisation. It is a process by which organically unavailable nutrient into plant-available forms to plants. The inorganic P releases through mineralisation become available and are taken by plants. For example, organic matter undergoes decomposing by soil microorganism and releasing the H^+ ions and chelates with Fe and Al as a result free the phosphate ions for sorption sites. The rate of mineralisation can be affected from varies factor such as climatic condition (rainfall and air temperature) and site conditions (soil moisture and aeration (oxygen level)) and salinity (salt content/electrical conductivity) as a result of decomposition of organic matter (United State of Department of Agriculture, 2014).

2.2.4 Immobilization

Immobilization is the reverse reaction of mineralization. It is defined as the transforming of soluble inorganic forms of P into organic forms of P. This process occurs when there is limited amount of inorganic nutrients in the soil make it temporarily available for plant uptake. Immobilization also happens simultaneously with mineralization in the soil (Osman, 2013). Through this process, it slows down the nutrients uptake by plants and it's affected the requirement demand of plants which then may contribute to lower yield as well as disturb their growth and development. Immobilization can ultimately result in nutrients deficiency. For instance, P ions will be bound to Fe and Al due to negatively charge itself and cannot move freely in the soil when the pH is lower causing the anions exchange capacity is increasing. This will affect the P become immobilize and become limiting factor to nutrients efficiency.

2.2.5 Present Concern with Soil P

The main problem that arises in agriculture sector is closely associated with P sorption especially in weathered by acid soil. As cited by previous researchers, P is have a great in influence on agricultural production in countries like Brazil (Novais; Smith, 1999), due to highly weathered Oxisols and Ultisols – where soils typically poor in this element. Another mentioned by researchers most of tropical soils (predominantly Ultisols and Oxisols) are acidic, where it causes the reducing P availability due to P-fixation (Ch'ng *et al*., 2014). An inadequate of P availability drives to P deficiency and severe problems in producing a good production and better growth yield. Limited of P nutrients will inhibit the crop growth performance such as stunted height; lessen the leaf growth and poor growth of roots development.

2.3 Common Management of P Fixation Problem

2.3.1 Chemical Liming

Liming is one of conventional practices used to regulate soil acidity particularly in tropical acid soils (Ch'ng *et al.*, 2014). Liming can increase the pH in highly acidic soil. It reduces acidic cations such Al, Fe, Mg, and Mn thus decrease the toxicity levels in the soil. Soil physical such as soil structure, porosity, and aeration can be improved through limed application. Liming can ensure an adequate supply of plant-available P by decreasing the concentration of Fe and Al ions solubility in soil solution (Ch'ng *et al*., 2014). However, liming may not always environmental friendly practices in fixing Fe and Al. Over-liming can increase the pH levels into alkalinity soil condition and cause precipitation of Ca fixed with P ions such as Calcium phosphate as described by Ch'ng *et al*. (2014). Thus, over-liming can result the P availability to decrease and micronutrients deficiencies.

2.3.2 Phosphorus Fertilizer Supply

The scenario of the P shortage has raised the concerned of farmers. The application of P fertilizer is an efficient way in enrich the P availability particularly in tropical acid soil. Consequently, the amount of P fertilizer has been rise markedly since from 1961 to 2007 as stated by Metson *et al.* (2012) indicated the global used of P is necessary and consumed has been continuously increasing. The imminent P crisis can be overcome by supplying adequate P fertilizer to the crop. P fertilizer improve the P availability with providing readily form of soluble inorganic P ions for crop uptake. Increased in P fertilizer application has provided the favourable outcomes of the crop.

However, the continuous or regular input of P fertilizer may result in excessive and unbalance where rising in environmental as well as health concern. The leaching of nutrients to the water bodies can cause eutrophication due to algae blooming (Ch'ng *et* *al*., 2014). A study by Schindler (1977), phosphorus is mainly factor causing eutrophication of water bodies due to over-enrichment or excessive by phosphate nutrients. The excessive of phosphorus inputs to water bodies generally originates from two types of nutrients source (1) point sources, and (2) non-point sources (Nasir & Mohammad, 2014). Typically, non-point sources such as runoff from agriculture sites, erosion of soil and degradation of soil (Nasir & Mohammad, 2014) have contributed a major factors driver of eutrophication in many regions (Carpenter *et al.* 1998).

Phosphate moves into the water bodies when there is only soil movement occur such as runoff or degradation of soil because phosphate is non water soluble forms as described by Nasir and Mohammad (2014). However, a crucial driver of nonpoint nutrient input is excessive application of fertilizer or manure, consequently leads phosphorus to accumulate within soils (Bennett et al. 2001).

Another conducted studied, stated the excessive inflow of phosphate into water ecosystem has the potential to cause increased algal growth which resulting to eutrophication in the aquatic environment (Kim *et al*., 2013). Phosphate affects the growth rate of organisms by acting as the limiting nutrient to the growth of plants in freshwater ecosystem (Kim *et al*., 2013) as well as causing death of fish (Ngatia *et al*., 2019). The algal growth affects the aquatic organisms which depleted the oxygen and causing aquatic organisms become fatal. Consequently, dissolved oxygen in water is reducing, hence causing organisms to die and decay. The excretion of toxic substances release from the decay products or blue-green algae and causing toxic effects present in water. Ngatia *et al*. (2019) revealed that consequences of phosphate eutrophication drives to detrimental effects whether wildlife animals, plants and human’s health.

2.3.3 Organic Amendments

Organic amendment is the supplement of any organic matter to the soil to improve its physical, chemical, and biological properties (Scotti *et al*., 2015). It used as productivity enhancer in modern agriculture. Most common organic amendments applied are wastes derived from agriculture waste such as manure and compost. Organic amendments as the potential in increasing the physical soil properties includes soil structure, water holding capacity, water penetration, and soil aeration (Ch'ng *et al*., 2014). Besides, they able to attracts and holds soil nutrients while induces slow mineral nutrients release in soil. This helps the plants can uptake the nutrients sufficiently due to reduce risk of nutrients leaching. It is made from sustainable natural resources and safe to use. As reported by Ch'ng *et al*. (2014) organic amendments can used to ameliorate the P-fixation. It increases the pH level by turning the acidic soil into slightly alkaline condition where able to reduce the exchangeable acidity and forms of Fe and Al. This is because the organic amendment has high affinity for both acidic cations as a result P become freely move in soil solution and readily and timely available for nutrient uptake.

Mineralisation and decomposition process of amendments improve the mild organic acid in the soil such as humic acids. The hydroxyl and carbonyl functional group of organic amendments chelate the cation bound to P such as Fe and Al and dissolve phosphate into soluble forms and make it more available for plant uptake (Ch'ng *et al*., 2014). Thus, organic amendments are very useful to mitigate the P-fixation and improve the P availability in acid soil.

2.4 Agriculture Waste

2.4.1 Rice Production in Malaysia

Rice becomes the most staple food to Asia population including Malaysia. In Malaysia, Norimah *et al.* (2008), reported that are about $2\frac{1}{2}$ plates of rice per day consumed among the adult as the c7onsumption pattern of rice, indicates a large number of production require in order to achieve the local requirement. Area and production of paddy rice in Malaysia are on the rise. Under 9th Malaysia Plan (2006 - 2010), the total area cultivated for paddy rice is 2, 474 ha and estimates will be increased years by years (Mohamed & Rokiah, 2006).

According to FAO statistic cited in Fact Fish website, Malaysia shows an increasing trend for rice production quantity (tons) years by years. It is about 1.82 million tons of the rice are being produces in 2017 year to achieve the nation requirement (Abdul, 2017). This clearly shown rice production is one of cultivation are given emphasises for domestic market and have increased farmers intention to growing these type of crop.

2.4.2 Waste produce

Recently, it was found that the rice production has indirectly contribute to large number of paddy residue neither rice husk nor rice straw in the production of rice. Paddy residue consists of paddy straw and rice husk as stated by (Shafie, 2015).

Malaysia, a principal rice growing region, has abundant rice residues which estimated at about 0.48 million tonne of rice husk (United Nations Development Programme, 2002) and 3, 76, 593.2 tonne of rice straw were produced yearly (Malaysia Economics Statistics, 2011). However, as reported by Shafie (2015), 3.66 million tonne of paddy residue were left in the field annually in Malaysia.

A high cost of rice residues removal from the field is the main reason behind open-air burning in the fields become common practice in Malaysia. This practice creates severe air pollution which later leads to greenhouse gaseous produce in greater amount. Other recent studied stated, open burning in the field significantly contribute environmental pollution, hazardous to human health, produces larger greenhouse gases generating global warming and results in loss of beneficial soil microbial diversity and plant nutrients like N, P and K (Singh *et al*., 2018).

2.4.3 Usage of waste

Rice husk used as a valued added raw material for different purposes (Kumar *et al*., 2013). Recently, rice residues can turns into one of valuable resources as biochar which used in agriculture purpose for increasing soil fertility (Milla *et al*., 2013). It possesses three polymer properties such as cellulose, hemicelluloses and lignin. Another research stated rice husk constitutes about 75-90% organic matter (Wallheimer & Brian, 2010) and 50% cellulose, 30% lignin, and 20% of silica (Mistry, 2016). Due to high content with lignin, rice husk is suitable to apply as fertilizer and substrate. It can acts as slow-release fertilizer because composting process of rice husk is very slow, thus the microbiota such as earthworm can used that time to composed the residues very efficiently. Therefore, it will prevent losses of nutrients such as N, P and K through leaching and runoff, slowing down the rate of volatized and better in nutrient retention.

Through vermicomposting process, rice husk can be converted and utilized as organic fertilizer. Rice husk used to improve crop productivity while increasing the water use with efficiency in the field (Govindarao, 1980). It also can be utilized as source of potassium for growth and yield that have been conducted on the cowpea crop (Priyadharshini & Seran, 2010). Rice husk also can be used as a substrate or medium for agriculture purpose used to combine with chemical fertilizer. It is most effective when used in combination with other chemicals, such as synthetic fertiliser (Steiner *et al*., 2007). Additionally, rice husk can use as biochar amendment that become a supplement to the soil to improve its physical, chemical and biological properties.

As mentioned by Baidoo *et al.* (2016), biochar amendment is a good agricultural soil management in improves the quality of problematic soils and enhances crop productivity by increasing growth rate and yield of the crop. Another studied by Milla *et al.* (2013) revealed that the response of water spinach to rice husk biochar gives a positive outcome in terms of plant growth, particularly in fresh plant weight. This is shown that biochar derived from rice husk able to exert positive impact in plant growth. The rice husk biochar supplemented soil resulted in greater increase in biomass production of water spinach by increasing in the stem size and leaf length.

The effects of rice husk biochar amendments also shown in previous studied that tends to improve water holding capacity (Milla *et al.*, 2013); increase the soil pH, thus increase available P, increase levels of organic content and aeration in the soil through increasing water retention and increase levels of exchangeable potassium (K) and magnesium (Mg) (FFTC, 2001).

2.5 Biochar

2.5.1 Definition

Biochar is defined as the conversion and utilization of organic waste through pyrolysis in zero or low oxygen environment. According to Hariz *et al.* (2015), biochar is a heating process of biomass product in a closed container without or limited presence of air and produced solid- carbon-rich product (Biederman & Harpole, 2013). It is environmental friendly product to improve soil functions, fertility and plant growth while preventing detrimental effect to environment as well as animal and human health. According to Ghani *et al.* (2010), stated the sources of biomass of rice husk considered abundant in Malaysia. The application of biochar in agriculture has been new in Malaysia but industry of production of biochar already existed for years. This biochar product has significant positive impact on soil and environment lead raising public concerns in applying biochar for agriculture.

2.5.2 Effect of Biochar in Crop Production

Biochar is best described as a soil conditioner (Hariz *et al.*, 2010). Study by Fellet (2014), biochar have significant role in improving soil productivity. Recent study by Yilangai *et al.*, (2014) proved that the effect of biochar amendment on tomato crop showed significantly higher result in stem growth and fruit yield. The adding of biochar to agricultural soils contributes benefits have been highlighted and supported by recent reviews (Glaser *et al*., 2002). For instances, biochar is able to promote the plant growth (Chan *et al*., 2008), increase the water-holding capacity of soil (Laird *et al*., 2010b) and reduces nutrients leaching losses and later benefits in reducing application of fertilizer needs (Liang *et al*., 2006).

As stated by Biederman and Harpole (2012), biochar is enriched with nutrients sources especially P and K. It can improve soil nutrients and this may able to promote the plant growth. Biochar associated with nutrients that come in the form of liable organic compounds and later available for plants after undergo weathering process (Yamato *et al*., 2006). According to Biederman and Harpole (2012), the concentration of P and K within plant tissue is increased when the application of biochar is applied to the tomato crop**.** Higher nutrients availability can enhance the plant to get adequate nutrients, thus increase the nutrients uptake as well as promoting the plant growth.

Research has shown biochar application also can improve soil water retention and soil aggregation thus decreases soil bulk density (Milla *et al*., 2013). Besides, according to previous studied (Oshio *et al*., 1981), rice husks as biochar also have the ability to increase the water holding capacity due to the carbonization process**.** It consists with micro-porous structure and a bulk density of about 0.150g cm^{-3} showed the rice husk ameliorate in water retention (Haefele *et al*., 2009). It is clearly indicate rice husk biochar has great potential and effective to improve field water holding capacity with highest water retention at 31.2% (Hariz *et al*., 2010)**.**

Biochar can improve soil water-holding capacity (Laird *et al*., 2010b) and provides soil water retention. Basically, water retention is increasing when the content of organic matter also increase. According to hypothesized made by Sohi *et al.* (2009), the application of biochar can increase organic content in the soils. The high organic matter level will enhance the availability of nutrients source, thus increase the nutrient uptake for plants.

2.5.3 Effects of Biochar in Soil Fertility

Biochar is a type of charcoal that is capable in replenishing, restoring and rebuilding soil fertility in degraded and problematic soils (Yilangai *et al*., 2014). Problematic soils typically acidic, less fertile, and low nutrients availability. Acidic soil has referred as a form of chemical degradation of the soil (Sung *et al*., 2017). Biochar additions have been used in the tropics due to their ability in improving soil chemical properties and nutrients availability especially P via reducing P sorption sites. It has the ability to enhance soil fertility and crop productivity. Biochar is considered to have a highly nutrient retention or holding within the soil. Nutrients within biochar need to be converted from organic to inorganic forms for making it available to uptake by plants. This will take a little bit of period for transforming process of organic nutrients but it will keep and preventing the nutrients from losses due to leaching especially nitrogen elements.

It also acts as slow-release fertilizer, where it alters the soil water nutrients transport from bypass through a matrix flow (Laird *et al.*, 2010a). As a result, this will induce the slow cation loss and reduce the risk of nutrients leaching as nutrients get absorbed onto the biochar surface (Laird *et al*., 2010a; Beck *et al*., 2011). It will give a longer period for plants to take up and absorb the nutrients by slowing down the leaching process. This will enhance the soil nutrient availability in the soils and provide sufficient nutrients source. Furthermore, biochar also classified as a natural liming agent. The neutralization characteristic having by biochar makes it capable to alter with physiochemical within soils. Normally, biochar products have different pH content as it depends on several factors such as temperature during pyrolysis process. For example, rice husk biochar have significantly value pH at 8.02 and this indicates it had slightly alkaline properties (Milla *et al*., 2013) while cacao shell have 9.8 pH value (Cornelissen *et al*., 2018). It will increase soil pH in highly acidic soil.

Addition of rice husk biochar will reduce the presence and mobilisation of toxic elements such as Fe and Al or soil's exchangeable acidity Al and extractable Fe which fix soil P are significantly reducing. Both of these elements cause the Phosphorus to bind with them and make the P nutrients unavailable for plants. Recent study stated, biochar potentially immobilize toxic substances (Mendez *et al*., 2012) and recover soil fertility. Therefore, declining in concentration of Al and Fe in aqueous nutrient soil will ensure the P freely to move and available to absorb by plants. As explained above, this is indicates biochar can be used to ameliorate P fixation in acid soils to increase crop production and fertility on acid soils.

2.6 Choy Sum

2.6.1 Choy Sum Physiology and Life Cycle

Choy sum (*Brassica chinensis* var. *parachinensis* is typically one of popular leafy vegetable crops and cultivated in Asian countries such as in Malaysia (Tin *et al*., 2000). It is one of Chinese flowering cabbage plant which enriched with vitamins and fiber as mentioned by Kamarudin *et al.* (2014). It is flowering plant which originated or native from China (Department of Economic Development, 2019) before the 15th century. Being a member of family *Brassicaceae*, choy sum is an annual for leaf production and has a short life cycle; can be harvested within one month (Kamarudin *et al*., 2010). The choy sum belongs to the genus *Brassica* of the mustard family, and come from Chinensis groups.

Department of Economic Development (2019) described choy sum is characterised by yellow flowers which located on stems with 0.5 to 1 cm in diameter and 15 to 20 cm long. The flowers starts to flowering when about 7 - 8 leaves presence on the plant and the height of the vegetable varies range from 20 – 30 cm. Choy sum leaves has come with distinctive colour and shape such as light or dark green; and oval or egg-shaped with slightly serrated margins. The maximum radius extending till to 12 cm and found the root system could achieve maximum depth at 12 cm in a soil.

Choy sum is categorized as leafy green, enrich with sources of nutrients that become important vegetables to human population, either for its stems or leaves. It typically used as a cuisine and also tender stems and leaves are used mainly as cooked vegetable. Both leaves and stem play a vital role to provide essential nutrition for human. As stated by Department of Economic Development, (2019) the choy sum younger leaves and flowering shoots particularly are consumed as salad or stir-fried, lightly boiled, steamed or added to meat.

According to Kamarudin *et al*. (2014) stated the Choy sum contains with high nutrition value such as 30.0 kcal of energy, 2.0 g of protein, 4.0 g of carbohydrate, 140.0 mg of calcium, 80.0 mg of phosphorus, 1.3 mg of iron, and 0.8 g of fiber. Choy sum are rich and comparatively cheap source of vitamins-B1 (Thiamine) such at the rate 0.09, 0.27, and 90.0 mg, B2 (Riboflavin) and C (ascorbic acid) in 100 g of edibles portion. Edible leaf vegetables are quite rich in antioxidants (Yadav *et al*., 2013; Miano, 2016). Antioxidant like ascorbic acid is necessary for synthesis of collagen and immunization system (Kamarudin *et al*., 2014).

Choy sum plant is a quick-maturing crop (Kamarudin *et al*., 2014) and short-season crop thus it have a short-life cycle (Department of Economic Development, 2019). Choy sum is distinctive vegetables due to ability to have short duration production cycles, high nutritive content and many vital minerals, quick response to manures and fertilizers, high yield, easiness in cultivation and suited to grow in agro-climatic situations make it favourite crop of farmers. Furthermore, it cultivated to meet with commercialized purpose due to high demand for human consumption where commercially for fresh market.

2.6.2 Climatic Requirement

A uniform conditions, moderate moisture level, and reasonable sunlight are most preferably by choy sum for cultivating as it is describe as a cool season crop (Moore & Morgan, 1998). However, cool climate will enhance grow rapidly and resulting short period cultivation obtains. Meanwhile, a higher temperature consequently in thinner, tougher and less sweet shoots or bolting problem as reported by Department of Economic Development (2019). Choy sum can be grown when the temperature are cool in order to get good quality (Cantwell *et al.*, 1996) and required the optimum temperature during harvest at range between 15^0C – 25^0C (Zee, 1975b).

2.6.3 Water Requirement

Choy sum plant has a shallow root system that makes them to thrive on a constant and uniform daily supply of water (Moore & Morgan 1998) in order to obtain a high quality plant such as maximum leaf production. It requires a high amount of water but the soil must have a good drainage to avoid saturated condition because choy sum is very sensitive to water stress (Kamarudin *et al.*, 2014) and dry conditions (Department of Economic Development, 2019). The crop need to water daily or twice daily for ensuring optimum growth and soil moisture must keep on as long not exceed beyond their water requirement during the choy sum production.

2.6.4 Soil Requirements

Choy sum grow well on a variety of soil types from light sands to clay loams (Department of Economic Development, 2019) but need fertile, rich with organic matter, as well as good-drained soils are most preferred as reported by Moore and Morgan (1998). The soil must have well-drained soils although the choy sum plant requires a plenty of water. However, they also do not tolerate with dry conditions as well as water logging (Kamarudin *et al*., 2014). The choy sum requires an optimum or ideal soil pH which nearly to neutral (6.0 – 7.0) and should not fall below 5.0 (Moore & Morgan, 1998).

2.6.5 Fertilizer

The crop must get an adequate nutrients based on range requirements for producing high quality of choy sum plants. Thus, an appropriate schedule of fertilizer needs to be adjusted respectively to the stages of growth and development. Choy sum requires the fertilizer application that able to promote higher regeneration of vegetation resulting to higher yield. As mentioned by Moore and Morgan (1998) these type of crop prefer a high fertile soil and enrich with organic matter. The NPK fertilizer can be applied in approximate amount where the rate for N, P and K are 0.25 g of N; 0.15 g of P; and 0.27 g of K as recommended by Anem (1970), respectively, using single fertilizer such as urea, TSP and MOP (Department of Economic Development, 2019)

2.6.6 Benefits Effect of Biochar Application on Growth of Choy Sum

Biochar has neutralizing properties that able to alter the chemical within the soil through complex physiochemical reactions with soil particles (Spokas *et al*., 2011). Previous research has shown that adding biochar to soil can improve soil pH level and becoming less acidic due to alkaline properties (Ch'ng *et al.*, 2014). Plant productivity can be improved with biochar application due to alkaline pH can increase the biomass production. In other word, biochar can acts similar and functions like liming, induces increases in soil alkalinity. As stated by previously researched, biochar pH is mostly neutral to basic but varies with types of biochar products. For example, rice husk biochar had slightly alkaline properties with a pH of 8.02 (Milla *et al*., 2013).

In acidic soils the P nutrients availability is limited (Steiner *et al*., 2008b), thus give impact to growth of the plants. Limiting agent of biochar is most effective in improving P availability by reducing the concentration of Fe and Al within soil solution (Cui *et al*., 2011). Biochar has higher affinity for Fe and Al and minimize P fixation in acid soils. High concentrated with Fe and Al can bind with the phosphorus which resulting unavailable form of phosphorus to plants. Thus, freely or soluble form of phosphorus becomes available for nutrients uptake and improves the growth and development of plant.

Biochar is contains negatively functional groups that preferably chelate acidic cation (Fe ions) bound to phosphate in alkaline solution and release the phosphate ions, thus minimizing P fixation in the soil (Ch'ng *et al*., 2014). This process will enable long-term chelation of Fe by biochar instead of P. Biochar is solid substances whose particles are very small, but have very large surface area and tend to be negatively charged. They attract and hold positively charged ions, but it preferable to bind with Fe instead of P. The decomposition of biochar release H ions (H_3O^+) from bonding sites (sites deprotonated) into the soil solution. The open site will attract other ions and adsorb to these sites of the surfaces of biochar.

Biochar contribute significant effect in soil nutrients by reducing leaching losses (Laird *et al*., 2010a). Recently reported by Liang *et al*. (2006) and Major *et al*. (2011), biochar can improve soil quality by increasing the cation exchange capacity and nutrient retention within soils, especially enhancing the P availability. This is due to biochar characteristics for having a porous structure, large surface area, and negative surface charge (Bird *et al*., 2008; Cheng *et al*., 2008; Downie *et al*., 2009).

Besides, biochar induce slow cation loss by controlling the soil water nutrient transport to shift into matrix flow rather than bypass (Laird *et al*., 2010a). Therefore, it reduces the risk of nutrients leaching as nutrients get absorbed onto the biochar surface (Laird *et al*., 2010a; Beck *et al*., 2011). It also suggested by researched paper, biochar have the ability to improve the availability of nutrients through soil liming and reducing leaching losses. As explained above, biochar may increase nutrient availability and affecting the growth by exerting positive impacts.

Another way biochar affect soil nutrients is increases in nutrient retention up on biochar addition to soils causing increases in crop productivity. Liang *et al*. (2006) and Major *et al*. (2011) previously stated biochar can increase the retention of nutrients, such as K within soil. It gives positive effect on the plant growth by ensuring well development of root, thrives the growth crops and plant productivity. This suggests that one of the main mechanisms behind the reported positive effects of biochar application to soils on plant productivity may be nutrient retention. Therefore, the choy sum crop can enhance their growth by increasing the P availability; improving an adequate nutrients, and nutrient retention while enhancing the physiochemical of soil.

2.6.7 Chelation of Al and Fe

Biochar can act in a similarly function to organic amendments. It is an important influential factor chemical, physical, and biological soil property. It can improve the soil chemical properties and minimize the P fixation (Ch'ng *et al*., 2014). P fixation can be reduced due to high affinity of biochar to Al and Fe. The high affinity mechanism of biochar induces the long-term chelation of Al and Fe instead of P fixation. Rice husk biochar is the stable, long lasting carbon containing substance, made of decayed plants and animals organic materials. Organic acid of hydroxyl and carbonyl functional group of biochar chelate the both acidic metal ions that used to bound to P. As a result the phosphate can turns into soluble P forms and thus, increase the P availability in the soil.

CHAPTER 3

METHODOLOGY

3.1 Material and Apparatus

The apparatus used in experiment were sieve, coring, auger, blender cup, measuring cylinder, hydrometer, pH meter, EC meter, crucible, plastic-ware, Muffle furnace, volumetric flask, conical flask, reciprocal shaker, extraction vessels, UV-Spectrophotometer Atomic Absorption Spectrometer (AAS), electronic balance, plastic pots, oven, and Whatman filter paper. A packet of Choy sum's seeds and a tray were used to planting.

3.2 Soil Sampling and Soil Preparation

The soil samples were collected at 0-20 cm from uncultivated land area in AgroTechnopark at Universiti Malaysia Kelantan, Jeli Campus Kelantan. About 20 sacks of soil sample were taken within a 50 m x 50 m randomly. The soil was open air-dried, ground, and sieve to pass through 5 mm sieve, respectively for laboratory analysis and pot study experiment.

3.3 Seedling Preparation

The seeds were sown in tray started from 11th to 18th of September 2019. The first cotyledons were emerged in 2-3 days after the first day of sowing. The seedlings were transferred into plastic pots with three density of seedling which located in greenhouse. The seeds were started sown at Sept. 19 2019 until Oct. 23 2019. The vegetables were watered daily at a constant volume which was 200 mL and fertilized with chemical fertilizer (N, P and K) at the rate 0.25 g of N; 0.15 g of P; and 0.27 g of K. The fertilizers were applied on 14th and 28th of DAP by equal split and harvested on Oct. 20 2019.

3.4 Soil Analysis

The soil sample was analysed for bulk density, soil texture, soil pH, soil electrical conductivity (EC), total organic matter, total carbon, soil exchangeable acidity, soil exchangeable Aluminium, and soil available P before the pot experiment was carried out.

3.4.1 Bulk Density Determination

Coring method used to determine soil bulk density (Dixon & Wisniewski, 1995). Coring was hammered into the soil to desired soil depth. Then, coring was removed carefully from the soil. The excess soils were trimmed. The coring fully with soil enclosed with plastic caps. Soils with coring were weighed and then oven dried at 105^{0} C until constant weigh was obtained. Bulk density was determined by using an equation described by Dixon and Wisniewski (1995).

Bulk density (g cm^{-3}) = Dry soil weight (g) / Soil volume (cm^3) (Eq. 3.1)

3.4.2 Soil Texture Determination

A hydrometer method was used in determine the soil texture of sample (Bouyoucos, 1962). A 50 g of soil sample was places in a blender cup. A few drops of 4 M of NaOH were added into blender cup to adjust the soil pH level to pH 10. The blender cup was filled with distilled water within 10 cm of the top rim. Then, the blender was placed on the stirred machine and mixed for about 15 minutes. Afterwards, the soil suspension was transferred into 1 L of measuring cylinder and distilled water was added into the measuring cylinder up to 1130 mL. The soil suspension was stirred using a stirring rod for 40 seconds.

After stirring, a hydrometer was placed into suspensions and the meniscus on the hydrometer stem was recorded. After that, hydrometer was removed and rinsed. The soil suspension was stirred again and the second reading of the hydrometer was recorded. The result obtained was evaluated for the amount of silt and clay of the soil in grams of the sample. After that, the soil suspension was stirred again and third hydrometer reading and temperature reading was taken after 2 hours of settling time. The calculation for soil texture is shown as below:

Percentage of sand + silt + clay = 100%

For 40 seconds reading:

Percentage of silt + clay = (a/50) x 100% = w (Eq. 3.2)

Percentage of sand = (100 – w) % = x (Eq. 3.3)

After 2 hours reading:

Percentage of clay = (b/50) x 100% = y (Eq. 3.4)

By difference: Percentage of silt = w – y = z (Eq. 3.5)

3.4.3 Soil pH and Electrical Conductivity Determination

The soil pH and electricity conductivity (EC) were determined using the potentiometric method with a ratio of 1:2:5 of soil; distilled water suspension using a digital pH meter and EC meter (Peech, 1965). A 10 g of air-dried soil in plastic vial at ratio of 1:2:5 was added into conical flask along with 25 mL of distilled water and the procedure was repeated for 3 samples. The samples were shaking for 15 minutes at 180 rpm using an orbital shaker. Later, the samples were left overnight for 24 hours before using a Beckman pH meter for pH determination and EC meter for EC determination.

3.4.4 Soil Total Organic Matter and Total C Determination

Soil total organic matter and total C were determined using combustion method as described by Tan (2003). The air-dried sample was placed in an oven at 60^{oC} and left for 24 hours. The sample was cooled down using a desiccator. The initial weight of empty and dry crucible was recorded (M_P). Then, crucible was filled with 5g of oven-dried soil and was recorded for their weight (M_{PDS}). Next, the sample was ashed at 300Oc in the muffle furnace for an hour and the temperature was increases to 540^0 C. The ashing process was continued for another 8 hours. Next, the crucible was took out using tong and allowed to cooling at the room temperature before inspection. The weight of sample in the crucible was weighed and calculated (M_{PA}). The total organic matter and C were calculated using the following equations (Tan, 2003):

Total Organic Matter content (%) =

$$\frac{Organic\ Matter\ Mass, MO}{Mass\ of\ Soil, MD}\ X\ 100\% = x \qquad \text{(Eq. 3.6)}$$

Where,

MD = Mass of oven-dried soil ($M_{PDS} – M_P$)

MA = Mass of ash (burned) soil ($M_{PA} – M_P$)

MO = Mass of organic matter ($M_D – M_A$)

Total C = SOM x 0.58 (Eq. 3.7)

3.4.5 Soil Available Phosphorus Determination

According to Mechlich (1953), Mechlich No. 1 Double Acid Method was used to extract the soil available P. A 4 mL of concentrated HCl and 0.7 mL of concentrated H_2SO_4 were pipetted into 1,000 mL volumetric flask and the volume was made up to volume. A 5 g of sample was placed into a 50 mL beaker. Next, 20 mL of extraction reagent was added. The solution was shaken for 10minutes on a reciprocal shaker. The supernatant was filtered into volumetric flask using Whatman Filter Paper No. 2. The extract was collected and pipetted into cuvette. The solution developed blue colour and was analysed by the Molybdenum Blue method (Murphy and Riley, 1962) using UV spectrophotometer at 882 nm wavelength.

$$\text{Total P} = \text{UV-reading} \times \frac{Volume\ of\ Double\ Acid\ (mL)}{Weight\ of\ sample\ (g)} \times \frac{Volume\ of\ Volumetric\ Flask\ (mL)}{Volume\ of sample\ added\ (mL)} \quad \text{(Eq. 3.8)}$$

3.4.6 Soil Total Exchangeable Cations (Fe) Determination

Mechlich No. 1 Double Acid Method was used to extract the soil exchangeable cations (Fe) (Mechlich, 1953). 5 g of soil sample was weighed and placed into 50 mL extraction vessel. Next, a 25 mL of the extraction reagent was added and the solution was shaked for 10 minutes on a reciprocal shaker. After that, the supernatant will be filtered into plastic vials using Whatman Filter Paper No.2 and the extract was collected. An Atomic Spectrometer (AAS) (Perkin Elmer Analyst 800) was calibrated and the extract was aspirated into AAS and the absorbance reading was taken. The soil exchangeable cations were calculated using equation shown below:

$$\text{Soil exchangeable cation (ppm)} = \text{AAS reading (ppm)} \times \left(\frac{\text{Volume of etractant (mL)}}{\text{Weight of soil sample (g)}}\right) \quad \text{(Eq.3.9)}$$

3.4.7 Soil Total Exchangeable Acidity and Exchangeable Aluminium Determination

According to Rowell (1994), soil exchangeable acidity and Al were determined using titration method. A 10 g of soil and 30 mL of 1 M Potassium Chloride (KCl) were placed in conical flask and left for overnight (24 hours). After that, the sample was filtered with Whatman paper No.2 into a 100 mL volumetric flask after 24 hours. The volume was making up to the mark. Next, 50 mL of soil extract was pipetted into 250 mL of conical flask. About five drops of phenolphthalein indicator was added. The solution was titrated against 0.01 M NaOH until the pink colour appeared. This method measured on the soil exchangeable acidity. The solution was titrated with 0.01 M HCl until the solution become colourless and this measured the soil exchangeable Al. The calculation will be outline as follow:

$$\text{Exchangeable acidity (cmol kg}^{-1}\text{)} = \frac{0.2\ x\ Titrate\ volume\ of\ 0.01\ M\ NaOH\ X\ 10}{Soil\ mass\ (g)} \quad \text{(Eq. 3.10)}$$

$$\text{Exchangeable Al (cmol kg-1)} = \frac{0.2\ x\ Titrate\ volume\ of\ 0.01\ HCl\ x\ 10}{Soil\ mass\ (g)} \quad \text{(Eq. 3.11)}$$

3.5 Pot Study

An acid soil was collected from the barren land of the AgroTechno Park at Universiti Malaysia Kelantan, Jeli Campus. The soil was air-dried and ground to pass a 5mm sieve. Choy sum (*Brassica chinensis* var. *parachinensis*), a famous grown Chinese cabbage, was selected and used as test crop for this study. The experiment was carried out in 18 plastic pots that filled up with specific amounts of soil which was conducted in a net house. The pots were filled up with air-dried soil that mixing with different rates of commercial rice husk biochar. The cultivation of Choy sum in the pot experiment was supplied with N, P and K fertiliser to ensure optimum growth of Choy sum.

Each of them was applied at are 0.25 g of N; 0.15 g of P; and 0.27 g of K. The soil samples were treated with varies amount biochar based on the treatment listed in Table 3.1. Each treatment had three replicates. One to three Choy sum seedlings were planted per pot. During the growing period, the water content of the soil in all pots was watering with water at 200 mL, and fertilizers were applied on 14^{th} and 28^{th} of DAP by equal split. The Choy sum was grown from Sept. 19, 2019 to Oct. 23, 2019. Treatments evaluated are as follows:

Table 3.1: List of treatments in pot experiment.

Treatment	Description
T0	5 kg of soil only (Control)
T1	5 kg soil + recommended NPK (0.25 g Urea + 0.15 g CIRP +0. 26 g MOP)
T2	4.75 kg soil + 0.25 g Urea + 0.15 g CIRP + 0.26 g MOP + 250 g biochar
T3	4.50 kg soil + 0.25 g Urea + 0.15 g CIRP + 0.26 g MOP + 500 g biochar
T4	4.25 kg soil + 0.25 g Urea + 0.15 g CIRP + 0.26 g MOP + 750 g biochar
T5	4 kg soil + 0.25 g Urea + 0.15 g CIRP + 0.26 g MOP + 1000 g biochar

3.6 Post-treatment Soil Analysis

After harvest the vegetable, the soil in each pot was air-dried, ground and sieved through a 5 mm sieve. Soil pH and EC was measured by a pH meter and EC meter at a soil/water ratio of 1:2.5. Soil total organic matter and carbon was determined by combustion method as described by Tan (2003). Phosphorus concentration in extracted solution was analysed by the Molybdenum Blue Method and the developed blue colour was analysed by UV spectrophotometer at 882 nm wavelength. Soil extractable Fe were extracted using Mehlich No. 1 Double Acid procedure as illustrated by Mehlich (1953) and extract was aspirated by AAS Soil exchangeable acidity were determined by titration with NaOH while soil exchangeable Al titrated with HCl.

3.6.1 Plant Growth Parameters of *Brassica chinensis* var. *parachinensis* Measurement

The Choy sum plant roots washed with tap water and followed by distilled water and open air-dried for further analysis. The plant height, number of leaves, root length, shoot root ratio, and fresh weight of shoot and root were measured immediately after harvest. The remaining plant materials were oven-dried at 60^{oC} for 24 hours and weighed by electronic balance to determine the dry weight of plants.

3.7 Experimental Design and Statistical Analysis

The experimental design used in this study was completely randomized design (CRD) with three replications. All statistical analyses were carried out with the Statistical Package for the Social Sciences (SPSS) version 9.3. The data were evaluated by Analysis of variance (ANOVA) to detect the treatment effects while the Tukey's test used to compare the treatments means $p<0.05$.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Selected Physico-chemical Properties of Soil Samples

Table 4.1 shows the selected physico-chemical properties of the soil sample prior to the pot experiment. The soil was sandy clay loam and had a low pH (3.71), low EC (0.1), low total organic matter (0.84), and low available P (0.22). The concentration of exchangeable acidity and Al were relatively lower while exchangeable Fe is quite high. This had caused the available P to be very low due to fixation of P by Fe.

Table 4.1 Selected physico-chemical properties of soil samples

Property	Value Obtained
Bulk Density (g cm^{-3})	1.47
Soil Texture	Sand -80%
	Clay -16%
	Silt – 4%
	Sandy Clay Loam
pH	3.71
Electrical conductivity (dS m^{-1})	0.1
Organic Matter (%)	0.84
Total Carbon (%)	0.49
Available P (ppm)	0.22
Exchangeable Acidity ($cmol_c kg^{-1}$)	0.13
Exchangeable Al ($cmol_c kg^{-1}$)	0.03
Exchangeable Fe (ppm)	69.6

4.2 Effect of Treatments on Selected Physico-chemical Properties of Soil after Pot Experiment

The selected physico-chemical properties of soil pH, EC, total organic matter, exchangeable acidity, exchangeable Al, available P, and exchangeable Fe after the pot experiment affected by the application of rice husk biochar was summarized in Table 4.2. The soil treated with mixture of chemical fertilizer and rice husk biochar (T2, T3, T4, and T5) showed increase in soil pH compared to control (T0) and soil treated with chemical fertilizer only (T1).

Soil pH increased along with the increase in application rate of rice husk biochar. The increase of soil pH was related to rapid proton exchange between soil and rice husk supplied thus contributed the liming effects to the soils. In another study stated biochar is created by heating organic material under conditions of limited or no oxygen (Lehmann, 2007) that producing ash, mainly contains minerals such as Ca or Mg. Ca is responsible elements that used to stabilize the pH within soil. Additionally, biochar also has a higher pH than the soil to which it is applied, thereby providing a liming effect. Biochar derived from rice husk consisted humic and fluvic acids through the decomposition of biochar within the soil. These acids possessed with carboxyl or hydroxyl functional group which captured the H^+ ions as well as Al and Fe (Ch'ng *et al*., 2014). Soil pH increased due to these mechanisms and decreased the acidic ions such as Fe and Al that causing the acidity of the soil.

The value obtained of EC from T1 to T5 showed no significant differences (Table 4.2) compared to treatment non-amended of chemical fertilizer and biochar (T0). The EC levels can serve as an indirect of the amount of water soluble nutrients available for plant uptake. T2 until T5 showed a significant difference with T0 due to application of biochar that help in increasing the amount of nutrients in water soluble form whereas T1 showed significant difference with T0 because of chemical fertilizer alone application. Chemical fertilizer used helps in providing the nutrients in the available forms that can utilize by plants.

Similarly, the application of biochar showed no significant difference in the percentages of organic matter in the treatment applied with biochar (T2, T3, T4, and T5). However, the T0 showed the lowest value obtained for the organic matter percentage. Organic matters adsorb those positively-charged nutrients such as Ca, K, Mg because they have negatively-charged sites on their surfaces and that can attract the positively-charged nutrients. A greater surface area can help the adsorption of positively-charges nutrients in higher rate and increase the cation exchange capacity. This allows the biochar can exchange these nutrients with plant roots. Soil contained a high cation exchange capacity, cause better nutrients retention. A lower of cation exchange capacity resulted in poor nutrients retention and the nutrients face a high risk for leaching and volatilization.

Total C showed no significant difference between T3, T4, and T5. While T1 and T2 also showed a similar result obtained indicates no significant difference between those rate of biochar used. T0 showed the lowest value obtained for total C in Table 4.2. Biochar is a C-rich and have potential in staying long in the soil and less susceptible to biological degradation. Biochar form humus which is C containing substances made of decayed rice husk and animals organic materials. It is generally organic because it is composed of chemical containing C, O, and H. This shows the C content increased using both chemical fertilizer and biochar as shown in Table 4.2. The higher percentages of organic matter also processed the total C in the soil because organic matter is the source of C (Zheng *et al.*, 2013).

Exchangeable acidity and exchangeable Al showed significant difference between treatment treated with biochar and non-biochar. The concentrations of trace elements such Al were higher at the soil without biochar (T0) and treated with inorganic fertilizers alone (T1). When the soil was applied with biochar, the concentrations of Al decreased because biochar has negatively charged sites on their surfaces which strong affinity to positive charged ion such as Al and Fe because opposite charges attract each other (Glaser *et al*., 2002). The application of biochar can decline of soil acidity and aluminium toxicity (Gwenzi *et al*., 2016), while increase of cation exchange capacity and nutrient availability, especially phosphorus, due to strong fixation in acidic soils (Albuquerque *et al*., 2014; Yuan & Xu, 2012).

The concentrations of P availability were lower at the soil without biochar. Meanwhile, the used of biochar amended in soil significantly increased compared than treatments without biochar (T0 and T1). However, the T1 have a high of P available compared to T0 due to applied CIRP fertilizer. T3 until T5 showed no significant difference between those rates of biochar used. High affinity of biochar for Fe and Al then chelate the cation bound to P and resulted phosphate freely move into soluble inorganic compounds. Relatively high affinity to Fe and Al in organic amendment might result higher available P in the soil (Ping *et al*., 2017). However, the increased rate of biochar applied also can decrease the P availability within the soil. This is due to precipitation of Ca fixed with P ions such as Calcium phosphate as described by Ch'ng *et al*. (2014).

Besides, significant difference in soil exchangeable Fe concentration was also observed in treatments treated with biochar compared with treatments without biochar amendments (T0 and T1) (Table 4.2). However, T3, T4, and T5 showed similar result obtained indicates there were no significant differences among the rate of biochar used to lower the Fe within soil. A reduced in soil exchangeable Fe concentration of treatments with organic amendments (T2, T3, T4, and T5) was because of the stronger affinity of Fe sorption on biochar. The exchangeable Fe reduced in soil with the application rate of biochar was partly relates to the increase cation exchange capacity induced upon applying biochar. Biochar has the potential to increase the soil CEC due to highly porous nature and higher surface area, which helps in increase sorption ability and base saturation as pointed out by Albert and Kwame (2018). This amendment results in an increase of CEC due to input from organic acid presence with functional groups such as carboxyl and hydroxyl groups served as exchange sites and with increase in the CEC, Fe were adsorbed and retained in the soil (Glaser *et al*., 2002).

Table 4.2 Selected physico-chemical properties of soil samples after pot experiment

Treatment	pH	EC (dS m^{-1})	Organic Matter (%)	Total C (%)
T0	4.44±0.24[c]	0.05±0.03[b]	3.34±0.55[b]	2.57±0.4[c]
T1	4.82±0.20[c]	0.53±0.18[a]	4.77±0.02[a]	2.77±0.1[b]
T2	5.00±0.75[bc]	0.56±0.10[a]	4.59±0.07[a]	2.81±0.07[b]
T3	5.33±0.42[bc]	0.57±0.11[a]	4.96±0.2[a]	3.12±0.1[a]
T4	6.31±0.67[ab]	0.62±0.04[a]	5.23±0.32[a]	3.17±0.41[a]
T5	6.85±0.49[a]	0.66±0.06[a]	5.33±0.08[a]	3.20±0.03[a]

Mean values within columns with different letter(s) indicate significant difference between treatments by Tukey's test at $p \leq 0.05$.

Treatment	Exchangeable Acidity	Exchangeable Al	Exchangeable Fe	Available P
	cmol kg^{-1}		**Ppm**	
T0	0.21±0.02[a]	0.06±0.01[a]	129.15±2.42[a]	1.56±0.03[e]
T1	0.19±0.01[a]	0.06±0.01[a]	74.72±5.72[b]	3.58±0.03[d]
T2	0.17±0.02[b]	0.07±0.01[a]	60.92±9.00[c]	5.71±0.07[c]
T3	0.13±0.01[c]	0.04±0.01[b]	49.99±4.35[d]	10.64±0.34[a]
T4	0.11±0.02[c]	0.03±0.01[b]	44.29±1.76[d]	10.76±0.14[a]
T5	0.10±0.02[c]	0.03±0.01[b]	42.79±1.38[d]	10.88±0.09[a]

Mean values within columns with different letter(s) indicate significant difference between treatments by Tukey's test at $p \leq 0.05$.

4.3 Effect of Treatments on Selected Plant Growth Parameters (Plant Height, Number of Leaves, Root Length, Dry Weight Shoot, and Dry Weight Root) after Treatments

Effect of treatments on selected plant growth parameters (plant height, number of leaves, root length, dry weight shoot and dry weight root) after pot experiment were summarized in Figure 4.1, Figure 4.2, Figure 4.3, Figure 4.4, and Figure 4.5. Treatments T3 and T4 had significant higher plant height than other treatments (Figure 4.1). Treatment T3 and T4 showed the significant highest plant height. Some studies revealed a small doses of biochar applied integrated with mineral fertilizers have increased the efficiency of these inputs (Manikandan & Subramanian, 2013). Biochar typically an organic amendment contains organic matter and able to improve microbial development. Those organic matters can act as nutrients storage as it contains humic and fulvic acids. Nutrients such as Ca, Mg, K and Na used to cling to the surface of humus.

Humic and fulvic acid is important to stimulate plant growth in terms of increasing plant height, dry or fresh weight, and improving nutrient uptake (Wright & Lessen, 2013) as well as root development. It stores nutrients as part of its own chemical composition but the nutrients are released for plant uptake when organic matter decomposes. Additionally, humic compound have greater potential in water holding capacity (Wright & Lessen, 2013) and can hold nutrients like sponge that very essential for plant growth and development. The plant roots can quickly access the available nutrients for plant growth and yield due to water stored within the topsoil. The biochar enhance the microbial productivity by degrade the humic substance which become primary constituents of soil organic matter. Addition of biochar to soil resulted in significantly larger plants growth than treatments without amendment. Early research found that humic acid and fulvic acid contributed a significant increase in root dry matter after exposing to humic compound in soybean experiment. Tan and Tantiwiramanond. (1983) also reported the nodule weight was increased but contrary with the number of nodules to increasing amounts of humic acid.

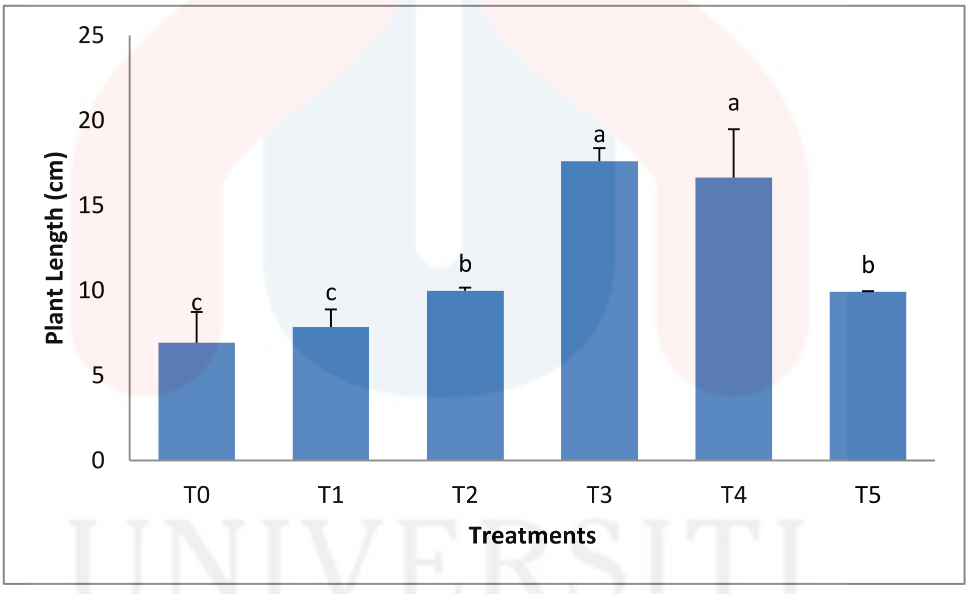

Figure 4.1 Effect of treatments on plant height of Choy Sum at harvest (30 DAS).

Mean values within columns with different letter(s) indicate significant difference between treatments by Tukey's test at $p \leq 0.05$.

Effect of treatments on the number of leaves of choy sum was shown in Figure 4.2. The T3 was showed significantly higher than those treatments. The numbers of leaves were significantly lower in T0 and T1 compared to biochar amended treatments because plant cannot produce the leaves with higher amount because of relatively low nutrients content in soil due to non-amended biochar. However, T1 was significant lower compared to T0. The T3 showed the maximum number of leaves produced because the plant utilized sufficiently on the biochar applied even though at the rates 500 g of biochar.

Biochar generally good in mitigate the P fixation, reducing the Al and Fe availability in the soil, enhanced soil nutrients, and nutrients uptake by plants (Jones *et a*l., 2016). Free moving ions of phosphates within the soil are used in photosynthesis, thus enhancing the plant growth development. As stated by Steiner *et a*l. (2007) application of biochar can increase soil C reserves, hold soil nutrients, enhance soil fertility, and increase crop yield. Phosphorus is crucial in cell division and cell enlargement (IFA country, 2019), thus it might affects the number of leaves produce by the plants. Similarly results were reported by Laekemariam and Gidago (2013) a significant effect on number of leaves per plants was found when the plants integrated with both organic and inorganic fertiliser. Makinde (2007) also showed that the positive effect on number of leaves per plants was partly related to the increased in application rate.

T1 is lower on number of leaves than T0 because of pests and diseases infection on the leaves of T1. The result obtained was because the unfavourable weather during the planting season has enhanced the pest infection growing on the leaves. The damage caused by pest leads to a loss in leaves produced. As described by Department of Economic Development (2019) there are many pests and diseases are major concern cause damage the brassica family such as aphids, caterpillars, white rust, and downy mildew.

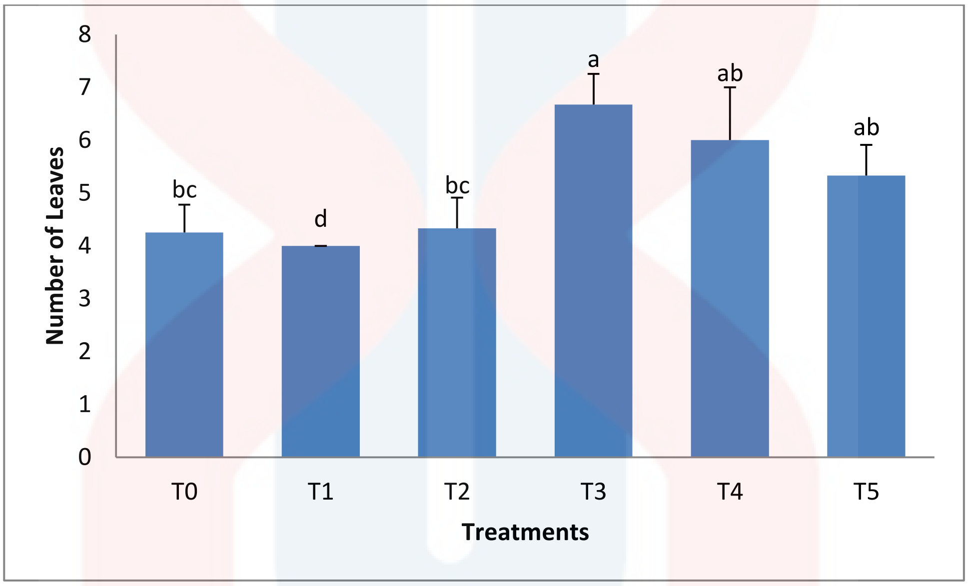

Figure 4.2 Effect of treatments on the number of leaves of Choy Sum at harvest (30 DAS).

Mean values within columns with different letter(s) indicate significant difference between treatments by Tukey's test at $p \leq 0.05$.

The effect of treatments on length of root of choy sum is presented in Figure 4.3. The length of roots was significantly higher in T2, T3, T4, and T5 compared to T0. This is because biochar is good in nutrient retention or nutrient holding capacity. A study by Silva *et al*. (2017) revealed that addition of biochar to the soil influenced the root growth of plants. The abundance of nutrient hold and capture by biochar significantly provide sufficient nutrients. The organic acids of the organic amendments may have out competed P for specific adsorption sites on the surface, hence the increase in the soil total P and available P concentrations. A negatively charged of biochar functional group might have out competed P for specific adsorption sites on the surface, thereby increase the availability of total P and available P for plant uptake (Violante & Gianfreda, 1993).

Reported by previous studied, root is crucial plant organs used to supply water, nutrients, hormones, mechanical support to plants and consequently can effects on crop yields (Fageria & Moreira, 2011). Enhancing a well-developed of root system which very essential for healthy plant growth and development. Fageria and Moreira (2011) mentioned mineral nutrition is one of environmental factors that primary factor in influencing the growth of plant roots. Root growth is measured in terms of root density, length, and weight. Biochar enriched with nutrients and with adequate supplied of nutrients resulted in decreasing root length (Fageria & Moreira, 2011) and this can be shown in Figure 4.3. Another studied revealed, biochar-induced increases in root length (Xiang *et a*l., 2017). P available is also evident in the significant elongation of root through the use of the biochar amendments (T2, T3, T4, and T5) in Figure 4.3 because it associated with the growth of root.

The increasing amount of biochar rates significantly increases the P concentration within a soil. Biochar is a good soil amendment that can increase the P availability by reducing the P fixation (Ch'ng *et al*., 2014). The biochar increase the P availability due to it roles in stimulating the root growth and development (Mosaic Crop Nutrition, n.d). However, Fageria and Moreira (2011) stated that a high amount of biochar resulted in greater uptake of nutrients and water and the accumulation of nutrients at the top soil will encourage the roots elongate shortly due to presence of abundant of nutrients. T5 showed minimum root length compared to T3 and T4 as recorded in Figure 4.3, even though amended with the higher rates of biochar. This finding was supported by Amendola *et al*. (2017) on grapevine fine root growth. Amendola *et al*. stated that cation exchange capacity, pH, and total and available P content are remained unaffected during plant growth and resulted fine root length remained unchanged.

Enriched with organic materials generally contribute to high carbon concentration in soil. The humic compound later degraded by microorganisms and consequently induces the humic acid (Wright & Lessen, 2013). This element help to stimulate the growth of root and shoot of corn crop as reported by Lee and Bartlett (1976). The plants showed a significant increase in terms of branching and root hair development when they were grown in a nutrient solution contained with humic acid. Another similar result also was reported on tobacco roots (Mylonas & McCants, 1980). However, used of this compounds at high concentrations also has been shown to decline the root and shoot growth (Lee &Bartlett, 1976; Mylonas & McCants 1980a; Mylonas & McCants, 1980b; Tan & Tantiwiramanond, 1983). This can explained the reason T5 showed the lowest root length among the treatments amended with biochar.

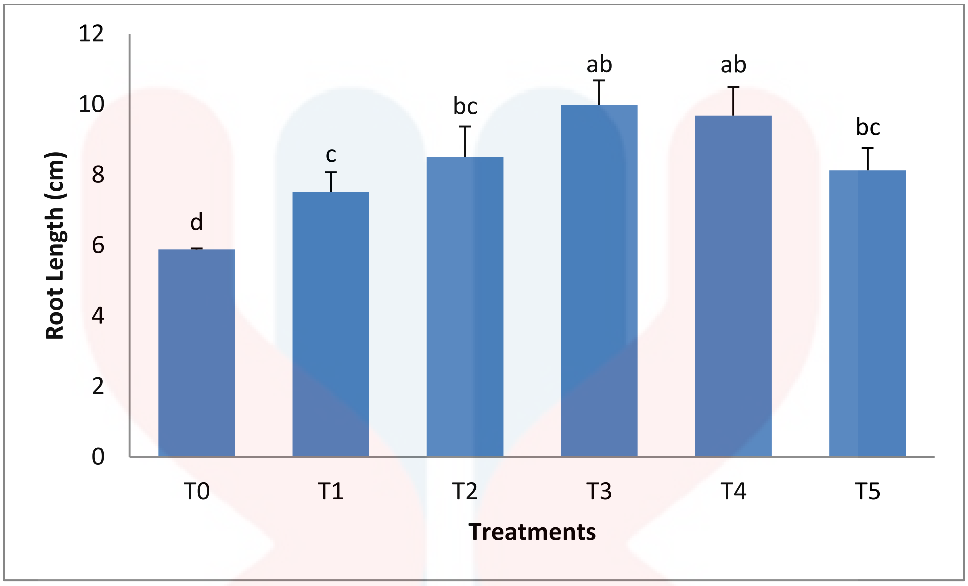

Figure 4.3 Effect of treatments on root length of Choy Sum at harvest (30 DAS).

Mean values within columns with different letter(s) indicate significant difference between treatments by Tukey's test at $p \leq 0.05$

The dry weight of shoot and root of Choy Sum were illustrated in Figure 4.4 and Figure 4.5. Non-biochar amended (T0 and T1) treatments showed lower in both dry weights compared to those treated with biochar (T2, T3, T4, and T5). The biochar amendments (T2, T3, T3, and T4) showed significant differences in both dry weights compared with non-biochar amendments (T0 and T1) because of the relatively high organic matter content in the biochar of T2, T3, T4, and T5. In the nutrient sufficient soil, root weight often increases with the addition of biochar. This observation is consistent with that of Fageria and Moreira (2011) who also observed significant increase in roots hairs growth with adequate nutrients supplies compared than nutrient-deficient root. Xiang *et al.*, (2017) also concluded that biochar-induced the number of root tips and root of nodules. These factors partly affected in weight of roots. This may result in greater uptake of water and nutrients well supplied with essential plant nutrients, compared with roots grown in nutrient-deficient roots. This can be observed when the treatments amended with biochar at the rate 500 g (T3) showed significantly increased in shoot weight than those treatments.

However, the T5 showed a lowest of both dry weights compared to T3 and T4. This might be due to lack of presence of P in soluble that aids in root growth and development. The decline in the dry weight of plant (T5) where a decline in nutrients uptake especially in P availability was ascribed to lower of P mineralization process. The rate of P mineralisation can be affected and varies climatic conditions (rainfall and air temperature) and site conditions (soil moisture and aeration (oxygen level)) and salinity (salt content/electrical conductivity) as a result of decomposition of organic matter (USDA, 2014). Lower in P availability associated with the temperature of particular regions. For instance, organic matter decomposes and releasing the P more quickly in warm, humid climates which contrast with a cool and dry climates (USDA, 2014). High water table also significant high levels of P are prone to loss of soluble P due to leach out, thus reduce the P availability within soil. Through this process, it slows down the nutrients uptake by plants and it's affected the requirement demand of plants which then may contribute to lower yield as well as disturb their growth and development.

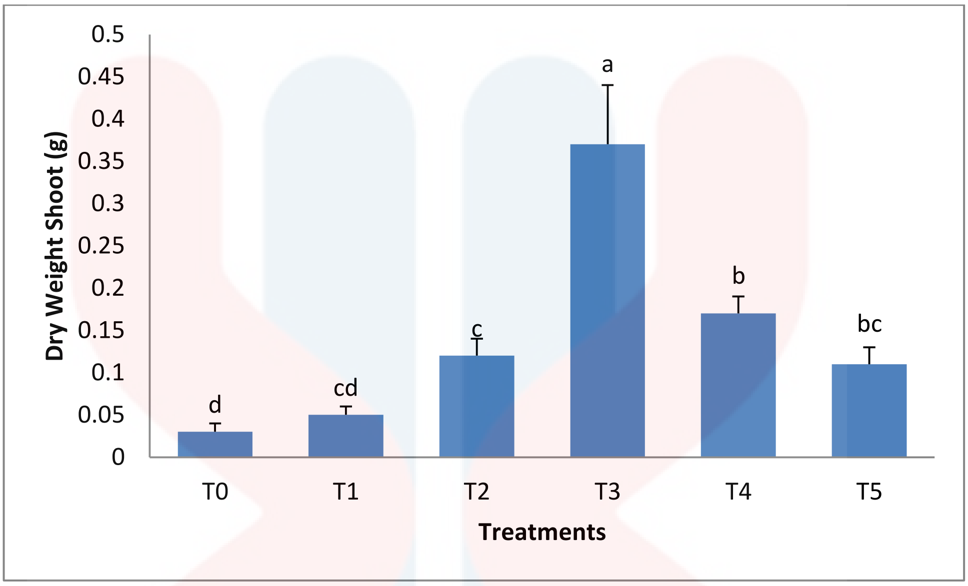

Figure 4.4 Effect of treatments on dry weight shoot of Choy Sum at harvest (30 DAS).

Mean values within columns with different letter(s) indicate significant difference between treatments by Tukey's test at $p \leq 0.05$.

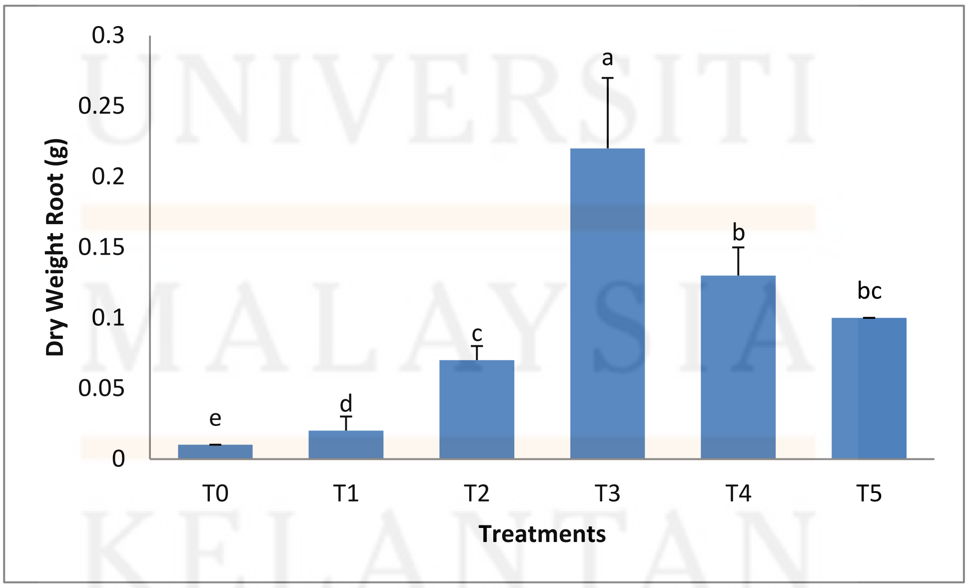

Figure 4.5 Effect of treatments on dry weight root of Choy Sum at harvest (30 DAS).

Mean values within columns with different letter(s) indicate significant difference between treatments by Tukey's test at $p \leq 0.05$.

4.4 Effect of Treatments on the Physical Growth Performance

The effect of treatments on the physical growth performance showed in the Figure 4.6., Figure 4.7, Figure 4.8, Figure 4.9, Figure 4.10 and Figure 4.11. As can be observed, there were differences in physical growth performance at 30 DAS. The control treatment (T0) showed the poorest growth performance compared to those other treatments. This explained the type of soil used in pot experiment were poor quality in nutrient availability due to acidic soil. Acidic soil is characterized as poor nutrient availability, less fertile, highly weathered, and high phosphorus fixation (Ch'ng *et al.*, 2014). Meanwhile, the treatment amended with chemical fertilizer only (T1) showed almost similar result to T0. The application with chemical fertilizer help in provide nutrient in available form for the nutrient uptake. The T0 showed an average number of leaves produced in all pots for treatment T1. However, T1 mostly have been infected with pests and diseases, consequently a lower growth performance in terms of number of leaves compared to T0.

The T2 showed slightly better growth performance compared to those treatments without biochar (T0). T2 showed increase in terms of height and number of leaves by using 250 g of biochar amended. Application of biochar in small dose could improve the test crop growth. The growth of performance of the choy sum plants with the treatments of chemical fertilizer amended with biochar amendments (T3 and T4) were higher than that of the chemical fertilizer only treatment (T1).Additionally, T3 and T4 showed the best growth performance among the treatments. The treatments were amended with biochar at rate of 500 g of biochar (T3) and 750 g of biochar (T4). The number of leaves produced was greater and also significant increase in their heights. This finding suggests a positive effect of combining biochar amendments and inorganic fertilizers on growth of choy sum plants. As stated by Ch'ng *et al.* (2016) both combinations ensured timely release of nutrients in the soil.

Additionally, the best growth performance signalled the plants in that particular amount of biochar are very essential in influencing the best growth performance as well as yield of the test crop. These explained the type of this test crop can be performed well in average doses of biochar used. This result is attributed to the general improvement of the soil environment in terms of increasing the soil pH, chelation of Fe and Al, increasing the Cation Exchange Capacity, as well as reducing the exchangeable acidity through application of biochar amendments. Another experiment conducted by Ch'ng *et al.* (2016) found that the combination of organic amendments and chemical fertilizers is beneficial in produced higher maize yield. This is because the organic amendments able to balance the releasing of nutrients and ensuring reduction of N, P, and K loss (Liu *et a*l., 2008).

In a similar study, Kimeto *et al*. (2004) also found that the combinations of organic amendments integrated with inorganic chemical exert positive impact in terms of higher maize yield. The findings of this result suggested that the biochar amendments can be used to ameliorate P fixation of acid soils to improve maize production on these soils. With the application of biochar and chemical fertilizers amended significantly increased the agronomic efficiency of P applied to the soils compared with chemical fertilizers. These both element applications in field experiment, which resulted in the increased P uptake by choy sum plants.

In contrast, the treatment treated with the higher rate of biochar (T5) is lower the growth performance compared to T3 and T4. The result might be influenced with the rate of biochar used for this type of crop. A large amount of biochar applied within the soil also cannot be exerted a positive impact on the growth and development of plant. The differences in growth performance between T5 and T3 and T4 could be the result of the difference in nutrient uptake which was low efficient in T5. Several studies also suggested declining in nutrient uptake especially in P was ascribed to lower of P mineralization process that causing from varies factor such as climatic condition (rainfall and air temperature) and site conditions (soil moisture and aeration (oxygen level)) and salinity (salt content/electrical conductivity) as a result of decomposition of organic matter (USDA, 2014).

Figure 4.6 Effect of T0 on the physical growth performance of Choy Sum at 30 DAS.

Figure 4.7 Effect of T1 on the physical growth performance of Choy Sum at 30 DAS.

Figure 4.8 Effect of T2 on the physical growth performance of Choy Sum at 30 DAS.

Figure 4.9 Effect of T3 on the physical growth performance of Choy Sum at 30 DAS.

Figure 4.10 Effect of T4 on the physical growth performance of Choy Sum at 30 DAS.

Figure 4.11 Effect of T5 on the physical growth performance of Choy Sum at 30 DAS.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

The treatment of biochar increased the soil P availability. The results of the present study suggest that rice husk biochar amendments can increase availability of P in a tropical soil. They can also increase soil pH to near neutral where the soil exchangeable acidity is reduced and such that the soil's exchangeable Al and exchangeable Fe which mainly fix soil P are reduced. As a result, P availability in the soil increased along with the increasing rate of biochar application. Additionally, the biochar amendments integrated with CIRP significantly fixed Fe instead of P, thus supply more available phosphate for a longer period compared with the application of CIRP alone without biochar amendments. In other words, it improves the soil P availability as well as enhances the selected plant parameters growth performance. Thus, the findings of this study further suggest or recommend that another physico-chemical of soil properties experiment carry out such as soil exchangeable cations (K, Ca, Mg, Na, Cu and Zn). This study also recommend to carry out plant tissue analysis in order to determine the nutrient uptakes by plants from the this kind of commercialized rice husk biochar used.

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APPENDICES

Figure A.1: Open air dried of soil samples.

Figure A.2: Oven dried of plant samples.

Figure A.3: Determination of soil pH.

Figure A.4: Determination of phosphorus availability