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ENHANCING PLANT GROWTH PERFORMANCE AND FERTILISER UPTAKE IN MAIZE (*Zea Mays* L.) CULTIVATED ON A TROPICAL ACID SOIL USING RICE STRAW COMPOST

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DECLARATION

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

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Student

Name:

Date:

I certify that the report of this final year project entitled "Enhance the Plant Growth Performance and Fertiliser Uptake in Maize (*Zea Mays*) Cultivated on a Tropical Acid Soil Using Rice Straw Compost" by Sia Zhi Yuan, matric number F15A0207 has been examined and all the correction recommended by examiners have been done for the degree of Bachelor of Applied Science (Agriculture Technology) with Honours, Faculty of Agro-Based Industry, Universiti Malaysia Kelantan.

Approved by:

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Supervisor Name:

Date:

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LIST OF ABBREVIATIONS AND SYMBOLS

N	**Nitrogen**
P	**Phosphorus**
K	**Potassium**
C	**Carbon**
Ca	**Calcium**
Fe	**Iron**
Mg	**Magnesium**
Zn	**Zinc**
Cu	**Copper**
S	**Sulphur**
NO	**Nitric acid**
NO_2^-	**Nitric**
NO2	**Nitrogen dioxide**
N_2	**Dinitrogen gas**
N_2O	**Nitrous oxide**
NO_3^-	**Nitrate**
NH_4^+	**Ammonium**
NaOH	**Sodium hydroxide**
HCl	**Hydrochloric acid**
H_2SO_4	**Sulphuric acid**
HNO_3	**Nitrate acid**

KCl	**Potassium chloride**
SOM	**Soil organic matter**
ppm	**Parts per million**
pH	**Potential of hydrogen**
EC	**Electrical conductivity**
TC	**Total carbon**
CEC	**Cation exchange capacity**
MOP	**Muriate of potash**
CIRP	**Christmas Island Rock Phosphate**
ATP	**Adenosine triphosphate**
C/N	**Carbon-nitrogen ratio**
C/P	**Carbon- phosphorus ratio**
CO_2	**Carbon dioxide**
H_2O	**Water**
MARDI	**Malaysia Agricultural Research and Development Institute**
SPSS	**Statistical package for social science**
DAP	**Days after planting**
ANOVA	**Analysis of varience**
ASS	**Atomic absorption spectroscopy**

LIST OF APPENDICES

Enhancing Plant Growth Performance and Fertiliser Uptake in Maize (*Zea Mays*) Cultivated on a Tropical Acid Soil Using Rice Straw Compost

ASTRACT

Nutrient deficiencies and environmental problem are common problems in tropical acid soil due to nitrogen volatilisation, phosphorus fixation and potassium leaching. The application of rice straw compost can be used to mitigate N, P, and K losses in acid by increasing nutrient availability in these soils. The aims of the study are to (i) characterize the selected physiochemical properties of the soil samples and rice straw compost, (ii) assess the selected plant growth parameters of *Zea mays* upon amending chemical fertiliser with rice straw compost, and (iii) determine the soil nutrients availability, total nutrient uptake, and dry matter production of *Zea mays L*. by amending chemical fertiliser with rice straw compost. A pot trial was conducted for 60 days and a F1 hybrid sweet corn 801 variety was used as a test crop. The soil samples were then collected and analysed at the end of pot trial. The maize was harvested and partitioned into leaves, stems, and roots at 60 during end of pot trial. The rice straw compost increased nitrogen, phosphorus, potassium, magnesium and calcium availability and increased the soil pH to near neutral due to the H^+ consumption capacity of organic materials. Nutrient availability in the soil was significantly increased due to microbial mediated mineralization causing an increased in available nutrients for plant uptake. The results also showed that the rice straw compost could increase the maize nutrient uptake and dry weight due to the high cation exchange capacity contributed by the rice straw amendments which increased the affinity of cations like ammonium, potassium ion, calcium ion and magnesium ion in soil. Treatment with 20 t ha^{-1} of compost had the highest nutrient uptake and cation exchange capacity due to higher rate of compost application which imposed larger surface area, and had the most abundant nutrient concentration in the leaves.

Meningkatkan Pertumbuhan Tanaman dan Pengambilan Baja pada pokok Jagung (*Zea Mays*) yang ditanam di Tanah Asid Tropika Menggunakan Kompos Jerami beras

ASTRAK

Kekurangan nutrisi dan masalah alam sekitar adalah masalah umum dalam tanah asid tropika akibat volatilisasi nitrogen, pengikatan fosforas dan larut resap kalium. Kompos jerami boleh digunakan untuk mengurangkan kehilangan N, P, dan K dengan meningkatkan ketersediaan nutrien dalam tanah. Tujuan kajian ini adalah untuk (i) mempercirikan sifat fisiokimia sampel tanah dan kompos jerami padi, (ii) menilai parameter pertumbuhan pokok jagung apabila diletakkan baja kimia dengan kompos jerami padi dan (iii) menyatakan ketersediaan nutrien tanah, jumlah pengambilan nutrien, dan pengeluaran jisim kering pokok jagung apabila diletakkan baja kimia dengan kompos jerami beras. Eksperimen pasu dijalankan selama 60 hari dan hybrid jagung manis variti F1 801 digunakan sebagai tanaman ujian. Sampel tanah dari setiap pasu ujian kemudian dikumpulkan dan dianalisis. Jagung dituai dan dibahagikan kepada daun, batang, dan akar pada 60 DAP. Kompos jerami beras dapat meningkatkan ketersediaan nitrogen, fosforus, potassium, magnesium dan kalsium dan meningkatkan pH tanah hampir kepada neutral disebabkan oleh kapasiti bahan organik yang mengkonsumsi H^+. Ketersediaan nutrien di dalam tanah telah meningkat dengan ketara disebabkan oleh mineralisasi mikrob yang menyebabkan ketersediaan nutrien untuk pengambilan tumbuhan meningkat. Keputusan juga menunjukkan bahawa kompos jerami boleh meningkatkan jisim kering dan pengambilan nutrien oleh pokok jagung yang disebabkan oleh kapasiti pertukaran kation yang tinggi yang disumbangkan oleh kompos jerami beras dengan meningkatkan afiniti kation seperti amonium, ion kalium, ion kalsium dan ion magnesium dalam tanah. Rawatan dengan 20 t ha^{-1} kompos mempunyai pengambilan nutrien dan kapasiti pertukaran kation tertinggi disebabkan oleh kadar aplikasi kompos yang lebih tinggi yang menyebabkan kawasan pertukaran kation menjadi lebih besar. Rawatan dengan 20 t ha^{-1} kompos juga mempunyai kepekatan nutrien yang paling banyak di daun.

Chapter 1

INTRODUCTION

1.1 Research Background

Soil acts as a storehouse of plant nutrients that provides nutrients in many forms. There is a total of 17 essential nutrients which can be divided into primary nutrients and secondary nutrients (Osman, 2013). Primary nutrients consist of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulphur(S). Nitrogen is among the most popular constituents consumed by the plants. Nitrogen acts as constituent of the chlorophyll molecules, that render the plant with green colour and allows it to trap solar energy from the sunlight and later converts it into the chemical energy through photosynthesis. Nitrogen content of plants varies from 0.2-6% of the dry weight basis (Osman, 2013). Phosphorus is also an important macronutrient which is needed for plant development. It acts as the constituent of nucleic acid (DNA and RNA), phospholipid as well as phosphoprotein. (Mullins, 2009). Besides, it is an essential constituent of enzyme and adenosine triphosphate (ATP) synthesis where energy is transferred between the adenosine diphosphate and adenosine triphosphate (Osman, 2013). During metabolic reaction, P content of plants varies from 0.1-0.5% of the dry weight basis. Potassium acts as the enzyme activator. It enhances the synthesis of protein and carbohydrate. It helps in regulating the opening and closing of the stomata which allows the diffusion of carbon dioxide, oxygen as well as water vapour. It aids in the regulation of osmotic potential of cells and tissues (Osman, 2013).

1.2 Problem statement

In most acidic soil, N deficiency happens due to the leaching of highly mobile ammonium (NH_4^+) as well as nitrate (NO_3^-) which make them less available for plant uptake. Nitrogen may also loss through denitrification where nitrate is converted into the N gas. Ammonia volatilization may occur where ammonia loss (NH_3) to the environment regardless of any forms of fertilisers applied, ranging from the anhydrous ammonia to the urea. These losses more likely to happen in wet and saline soils (Park, 2009). Phosphorus deficiency occurs due to fixation of P with the abundant Al and Fe in acidic soil. This is due to iron (Fe) and aluminium (Al) become highly mobile and major soluble cation in the low pH soil. The reaction between soluble P ions and Al as well as Fe causes the formation of insoluble phosphate (Bryan and Jason, 2005). The presence of amorphous or partially crystallized Fe and Al oxide that can occlude P as they crystallized in acid soil causes less available P for plant uptake (Osman, 2013). Potassium is highly vulnerable to loss by leaching (Mohsen, 2007). The leaching of K is a major problem in sandy and silt soils as sandy and silt soil have a low cation exchange capacity (CEC) and do not have a large K^+ fixing capacity. (Jalali and Rowell, 2003) This has increased in public concern as excessive application of K^+ fertilizer bring negative impact on water quality.

Since N, P and K losses are progressively increased, most farmers tend to supply higher amount of fertiliser in order to maximise the production of the crops. This excessive application of fertilisers (N, P, and K) will cause the accumulation of excessive fertilisers in the farm and result in severe environmental problems. In this case, nitrate levels have increased for both surface and ground water supplies. The presence of NH_3 and oxides of N in the atmosphere caused by volatilisation and denitrification from soils may cause detrimental effects from human health to 'polluted' non-agricultural ecosystems (Newbould, 1989).

Extensive P fertiliser application in the soils may cause the accumulation of heavy metals in intensive cropping lands may be one of the environmental impacts (Allaway, 1971). This phosphorus may be washed away into the water pathway and lead to eutrophication. The leaching of P fertiliser in the waterways which result in algae booming and the depletion of oxygen in the water consequently fatal to the aquatic organisms (Rohlich et al., 1980). Liming in acid soils can improve the P availability by increasing the soil pH. However, over liming will again induce P deficiency. Great amount of K may cause a negative impact to the soil organism. High level of K can bring a negative impact on the soil pH, soil structure deterioration besides increasing the feature for acid irrigation (Swapna and Bhandarkar, 2015).

More than 3.5 billion people consume rice every day and the demand is believed to increase up to 70% with the increased Asia population (Yogambigai et al, 2015). Rice is the most important staple food in Malaysia. According to Norimah (2008), the consumption pattern of rice among the adult in Malaysia are about 2½ plates of rice per day. About 1.82 million tons of the rice are being produced in 2017 year to achieve the nation requirement (Abdul, 2017). This large number of rice production has indirectly contributed large number of paddy residue (rice husks and rice straws). In Malaysia, Shafie et al (2014), reported that 0.48 million tonnes of rice husk and 3, 176, 593.2 tonnes of rice straw were produced yearly. By contrast, it is costly to remove the rice straw after harvesting and methane emissions take place if the residues are broken down anaerobically. Therefore, open-air burning of rice straws becomes common practice in Malaysia to eliminate such waste. The open burning of field straw has contributed to 1521.53 kg of carbon dioxide from each tonne of the paddy residue. The problem with the pollution will later extend toward the health issue and air quality (Shafie et al., 2014). In some extent, rice straw can be used as the feedstock for cattle (Nazli et al, 2017) and the source of fuel ethanol production (Shafie et al, 2014).

In this case, adding value to the wastes can be one of the challenges in managing agriculture waste in Malaysia, for example, converting the rice straw into compost. Compost is an organic fertiliser and could act as organic amendment. It increases soil nutrient, soil organic matter as well as improve soil physical, chemical and biological properties. It enhances soil porosity, soil structure, soil water holding capacity as well as soil erosion control (Tomasz et al, 2017). Compost produced from rice straw could be used to reduce N volatilisation, P fixation, and K leaching in acid soils. Although there are some information regarding the N and K leaching as well as P fixation using organic matter (Li et al., 2007), there is a dearth of information on the application of rice straw compost in resolving N, P, and K losses in acid soil. One of the reasons for it is due to the high affinity towards Al and Fe of the rice straw compost. A chelation of rice straw compost is formed by the strong affinity between the compost, Al and Fe instead of P. Besides, rice straw compost has high cation exchange capacity (CEC) as well as changes in soil will increase nitrate and ammonium absorption. Hence, all the nutrients will be utilised effectively.

1.3 Research Question

If the acid soil with less N and K available for the plant uptake due to leaching, can it be solved by the rice straw compost with higher cation exchange capacity and retained these nutrients on top of the soil for plant uptake? If the acid consists of less P available to the plant uptake due to P fixation by the presence of highly mobile and yet soluble Al as well as Fe, can it be solved by the rice straw with the negatively charged humus coating with Al and Fe oxide which making the P more readily to be uptake by plant?

1.4 Objectives

The objectives of this study are to:

1. Characterize the physio-chemical properties of the soil samples and rice straw compost
2. Assess the selected plant growth parameters of *Zea mays* (plant length, number of leaves, leaf area index, leaf area ratio, and root length) upon amending chemical fertiliser with rice straw compost.
3. Determine the soil N, P, and K availability, total N, P, and K uptake, and dry matter production of *Zea mays* L. by amending chemical fertiliser (N, P, and K) with rice straw compost.

1.5 Scope of study

This study focuses on the way to enhance the plant growth performance and fertiliser use uptake in maize cultivated on a tropical acid soil using rice straw compost.

1.6 Significance of study

This study focuses on the N, P and K chemical fertilisers inputs to the acid soil in Malaysia and it also fully make use of agricultural waste like rice straw.

1.7 Hypothesis

H0: Amending chemical fertiliser with rice straw compost will not exert positive impact on the selected plant growth parameter of *Zea mays* (plant length, number of leaves, leaf area index, leaf area ratio and root length), soil N, P and K availability, total N, P and K uptake, nutrients use efficiency and dry matter production of *Zea mays L.*.

HA: Amending chemical fertiliser with rice straw compost will exert a positive impact on the selected plant growth parameter of *Zea mays* (plant length, number of leaves, leaf area index, leaf area ratio and root length) soil N, P and K availability, total N, P and K uptake, nutrients use efficiency and dry matter production of *Zea mays L.*.

Chapter 2

LITERATURE REVIEW

2.1 Nutrient cycle in soil

2.1.1 Nitrogen cycle

Atmosphere is the main source of N (78%). Some of these N is brought to the soil from the atmosphere through the process of biological fixation, lightning and precipitation. A large amount of N can be supplied as chemical fertilisers manufactured by the industries. These native as well as added soil N are absorbed by the plants as a source of nutrient to synthesis chlorophyll, nucleic acid, protein and other substances. The plants are consumed by the primary consumers as a source of proteins and energy (Bryan and Jason, 2005). Biological N fixation is carried out where certain microorganisms may or may not corporate with plants when the utilisation of dinitrogen from our atmosphere. A significant number of organic N returns to the soil, when the animals and plants die or excrete. These residues may be crop residues, carcasses and faeces. The organic N may undergo mineralisation to convert into inorganic N – nitrate, NO_3, by microbes. Ammonium undergoes nitrification to convert into NO_3-. The atmosphere regains N when ammonia volatilization and nitrification of nitrate occur (Figure 2.1.1). In short, the biological processes involved in the N cycle include immobilisation, mineralisation, N fixation, denitrification as well as nitrification (Osman, 2013).

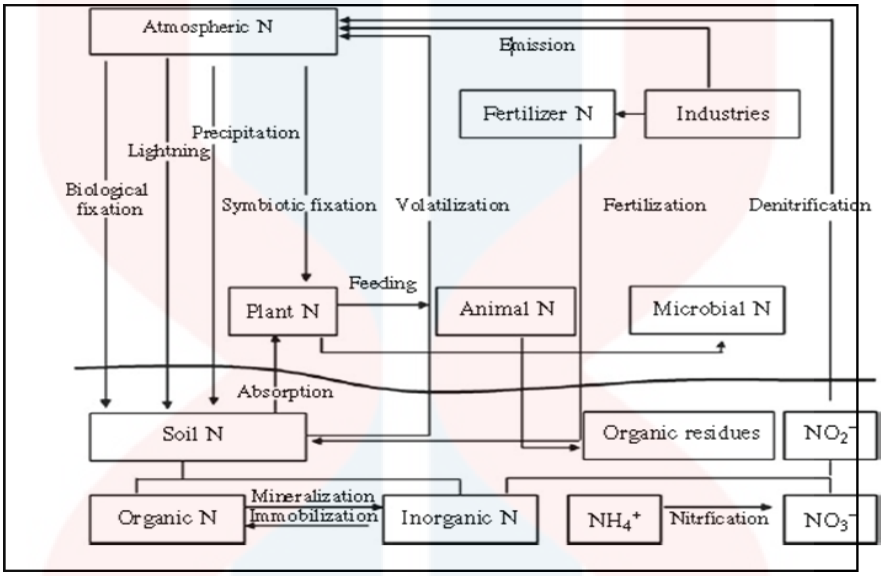


Figure 2.1.1: Soil nitrogen cycle (Osman, 2013)

2.1.2 Phosphorus cycle

The main reservoir of soil P is rock and mineral apatite. Available P is returned to the P cycle by weathering, human extraction as well as erosion. Chemical fertilisers can also be a source of P. These native as well as added soil P are absorbed by the plants and microorganisms as a source of nutrient to synthesis ATP, nucleic acid, phospholipids and proteins (Osman, 2013). Phosphorus immobilisation occurs to convert soluble inorganic P into organic P in plants and microbes. These P in the plants are transferred to the protoplasm of animals through feeding. The P in plants or animals can be convert back to dissolved P through action of phosphating bacteria in the decomposing process, excrement released by plants or animals and in the bones and teeth of death carcasses. The process of conversion of organic phosphate into inorganic P is known as phosphorus mineralisation. Most of these dissolved phosphate leaches into the groundwater or ocean where some of the P are deposited in shallow marine deposits (Figure 2.1.2). Small proportions of phosphate in shallow marine deposits are returned as apatite through geological land uplift. In short, the biological processes involved in the phosphorus cycle include weathering, precipitation, immobilisation, mineralisation, sorption and desorption (Osman, 2013).

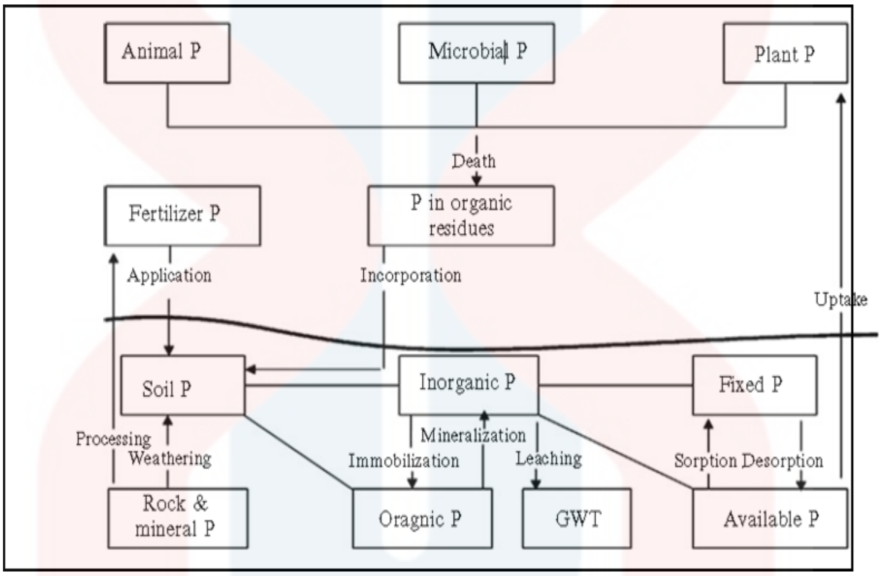


Figure 2.1.2: Soil phosphorus cycle (Osman, 2013)

2.1.3 Potassium cycle

The main reservoir of soil K is Feldspar and mica. Available K is returned to the K cycle by weathering, mining activities as well as erosion. A large amount of K can be supplied as chemical fertilisers (Korb, 2002). These native as well as added soil K are absorbed by the plants as a source of nutrient. High cation exchange capacity (CEC) clay affects fixation and release of K through sorption and desorption (Korb et al, 2002). Nonexchangeable or fixed K are unavailable for plant uptake and exchangeable K are available for plant uptake. Plants or animals' residues (manure, dead bodies and wood ash) return a large proportion of K to the soil. Some may lose through leaching, runoff and soil losses. In short, the biological processes involved in the K cycle include weathering, mineral weathering, erosion, clay fixation and release, adsorption and desorption, runoff or leaching (Figure 2.1.3).

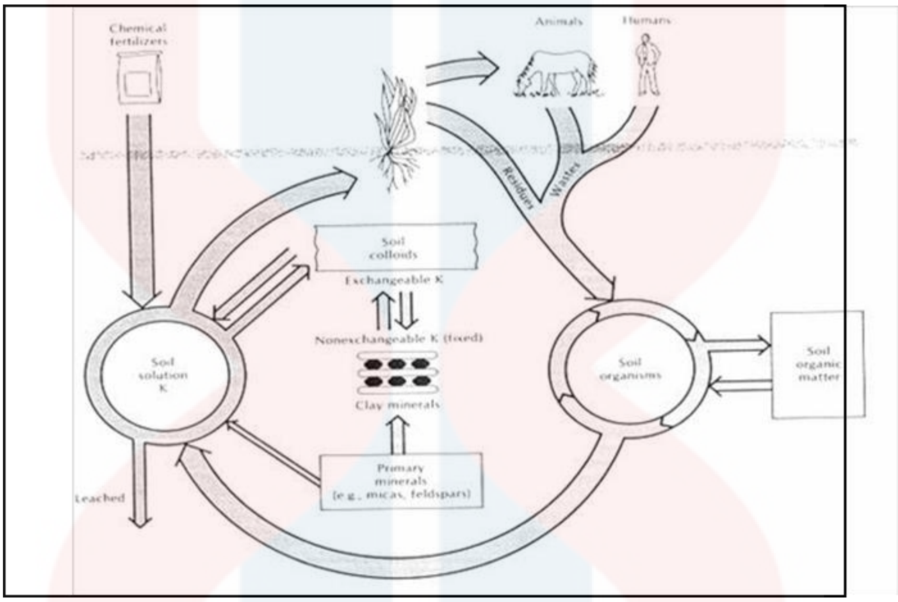


Figure 2.1.3: Soil potassium cycle (Brady, 1990)

2.2 Soil fertility

2.2.1 Function of plant nutrient N, P and K

Nitrogen acts as constituent of the chlorophyll molecules, nucleic acid (RNA and DNA) and several components of vitamin such as thiamine. It acts as constituent of proteins which is used in protoplasm synthesis. It enhances vegetative growth by accelerating cell division. As a result, the numbers of leaves increase and the elongation of internode, stem as well as branches. Phosphorus (P) acts as the constituent of nucleic acid (DNA and RNA), phospholipid as well as phosphoprotein. (Mullins, 2009). Besides, it is an essential constituent of enzyme and adenosine triphosphate (ATP) synthesis where energy is transferred between the adenosine diphosphate and ATP (Osman, 2013). It is very important in the early development of plants as it accelerates germination of seed, growth of seedling, fruits as well as flowers. Potassium acts as the enzyme activator. It enhances the synthesis of protein and carbohydrate. It helps in controlling of stomata opening and closing which allows the diffusion of carbon dioxide, oxygen as well as water vapors. It aids in the regulation of osmotic potential of cells and tissues. (Osman, 2013).

2.2.2 N, P and K deficiency

Deficiency of N can cause pale yellow of the older leaves or chlorosis and stunted growth such as fewer leaves and branches are produced (Rattan, 2006). This deficiency is caused by the reduced in chlorophyll synthesis and highly mobility of N within plants. Deficiency of N causes stunted growth and less leaves and branches produced. As a result, it causes lower yield. Deficiency of P causes purplish leaves on the margin of the leaves can be seen easily. Besides, the shoot and root growth will reduce. Carbohydrate metabolism will slow down which result in darker colour of leaves (Patiram et al, 2007). It reduces the quality of leaves and fruits due to the delayed in maturity as well as reduces disease resistance. Potassium deficiency will show a marginal burning of leaves as well as curling of leaves. Deficiency of K causes poor root development and slow down the growth of crops. Lodging of corn can occur. Besides, the seeds may be smaller and shrivelled (Osman, 2013).

2.2.3 N, P and K toxicity

Too much N can cause a delay in the initial flowering and fruiting consequently lead to the reduction of yield. Pest and disease can infect the plant easily as it has become tender and succulent. Nevertheless, the crop quality may be reduced. As for the excess P which will induce K, Fe and Zn deficiency whereas excessive K may lead to Ca and Mg deficiency (Mullins, 2009).

2.3 Nutrient dynamics in the soil

2.3.1 Mineralisation and immobilisation

Mineralisation is defined as the conversion of organic forms of N, P and K to inorganic forms of N, P and K by a range of heterotrophic microorganisms. Through this process, organically unavailable nutrient becomes available to plants. This is a slow process where the nutrients are supplied corresponding to the needs in plant growth. Rate of mineralisation can be affected by the soil temperature, soil pH, high organic nutrient content and the C/N ratio. Immobilisation is opposite to mineralisation where inorganic forms of N, P, and K are converted to organic forms of nutrients N, P, and K. This process occurs when there are low nutrient residues in the soil which make it temporarily unavailable for plant uptake. The two processes occur simultaneously in the soil (Osman, 2013).

2.3.2 Plant nutrient uptake

Plants absorb soluble and exchangeable N, P, and K in the soil. In such cases, plants can uptake N in the form of NO_3^- and NH_4^+ (Wild, 1988). They uptake P mainly as primary orthophosphate form (H_2PO^-) whereas K^+ for K. The main factor that affect the crop production and plant uptake are the nutrient availability. Presence of more nutrients in the soil will increase plant uptake, however, plants will not grow further if the nutrients are saturated. Mineralisation is another factor which contributes to the nutrient availability in the inorganic forms of nutrients. Higher rate of mineralisation will lead to greater nutrient availability for plant uptake. Besides, pH also regulates the availability of nutrients to the plants (Duong et al, 2012).

2.3.3 Leaching

Leaching is the process where nutrients loss by percolating water through the soil profile (Benbi and Richter, 2003). Overuse of chemical fertiliser will cause leaching of nutrients elements including N, P, and K from farm to water pathways. According to a tracer study done by Sebilo *et al*, (2013), 8-12% of synthetic fertilisers were leaked toward water pathway and groundwater during a 30 years observation period. The increased in urea application was significant positive correlated with the increased in nitrate concentrations in the water pathways (Sebilo *et al*, 2013). Consequently, the leaching of nutrient to the water pathway may cause eutrophication, algae blooming in the aquatic ecosystems. This will cause the marine organisms in the freshwater ecosystem to be fatal. Similarly, Sarby (2015) proved 33% of the P fertilisers applied to the soil might be lost through soil erosion and leaching. Thus, farmers tended to apply excessive P fertilisers to ensure the availability of P to the crop plants which resulted in the increased in costing and risk of run-off. These nutrients leached out from soils may cause reduction of crop production, acceleration of soil acidification, depletion of soil fertility and threaten to abiotic environment (Yao et al, 2012).

2.3.4 Volatilisation

Volatilization is the transformation of N and losses from soil to the atmosphere in the form of NH_3 (Osman, 2013). Volatilisation usually occurs in soils with higher pH (7.5 and above), high wind speed, and high soil temperature (Li *et al*, 2008). This is because higher soil pH will increase soil NH_3 concentrations dissolved in soil water while warm soil water cannot hold much NH_3 gas (Xu *et al*, 2013). Previous studies suggested that N lost through volatilisation ranged from 10-50% of the 19.2 million tonnes of synthetic chemical fertiliser supplied annually in the global rice production systems (Coskun et al., 2017). According to research done by Hofmeier *et* al, (2014), approximately 36% of applied N was lost during rice production through denitrification and 79 kg N ha^{-1} or 22.3% of N was lost during the rice growing season. Such loses in NH_3 might contributed to high deposition and secondary deposition of NH_3 might further produces nitrous oxide emission which resulted in global warming (Hube *et al*, 2017).

2.3.5 Adsorption and desorption

Phosphate sorption and desorption are sometimes known as P fixation in soil. This process involves the transfer of phosphate ions from soil solution to solid phase (sorption) and the release of P from solid phase into the soil solution through plant uptake, leaching and runoff (desorption) (McBride, 2000). The main problem that arises in agriculture sector is closely associated with P sorption especially in weathered by acid soil. Precipitation with Fe and Al by colloids lead to anion exchange capacity between the phosphate anion and the elements. As a result, such chelate P tightly inhibit the plant uptake due to the strong bond between them which has caused P deficiency in tropical acid soil (Adnan *et al*, 2003). Previous studies suggested that P uptake can be enhanced by applying organic amendments (DeLuca *et al*,2009). In a related study done by Ch'ng *et al* (2015), has further revealed a significantly increased in P sorption with organic amendments at low P concentration (< 10 mg L^{-1}). The same study showed more P was released by desorption at 10-20 mg L^{-1} P application rate.

2.3.6 Cation Exchange Capacity

Cation Exchange Capacity (CEC) is the sum total of the sum of cations displaced from soil in concentrated salt solutions (Rengel and Robinson, 2012). The CEC is used to measure the capacity of a soil to hold exchange able cations. The main sources of CEC are clay minerals and organic matter. Isomorphous substitution and pH dependent charges are the two main sources of charge in clay mineral. Isomorphous substitution is the substitution of one ion with another ion with the same size in an ionic crystal without changing the structure. Substitution between Si_4^+ and Al_3^+ or Fe_3^+ are commonly happens in the acid soil. These will give rise to the overall negative charge and high CEC in the acid soil. Highly decomposed organic matter is known as humus which consists of humic and fulvic acids. Humus with lower negative charge may contribute lower cation exchange capacity (Havlin *et al*, 2005). Thus, cation like K^+ and NH_4^+ are likely to adhere to the humus. Therefore, K deficiency occurs in this kind of soil with low CEC and more susceptible to leaching.

2.4 Factors affecting nutrient in the soil

2.4.1 Soil Organic Matter

Soil organic matter (SOM) is an essential component in the soil. It is one of the factors affecting nutrient in the soil. Its entity is highly varied due to different stage of decomposition. Decomposition of organic matter may produce three fractions of materials which are humic acid, fulvic acid and, humin. (Osman, 2013) These organic acids produced dissolve soil minerals and make nutrients more available to the plant uptake. This will protect the P nutrient from being bounded to the Al and Fe presence in the soil and make it more available to the plant. Besides, high affinity of the carboxyl and phenol groups in soil organic matter may increase the occurrence of adsorption toward the positive sites on Al and Fe oxides which increase the nutrient availability for plant uptake (Thong *et al,* 2011). Previous researches suggested that long term dependence on synthetic fertilisers N showed a pronounced declined in SOM, worldwide (Ladha *et al,* 2011). SOM in land without synthetic fertiliser N was 8-10% higher than those with a synthetic fertiliser input (Bruulsema, 2018).

2.4.2 Clay Content

Soil texture with a higher clay content has higher nutrient availability particularly in tropical acid soil. Clay soil possesses higher nutrient and water holding capacity. Clay soil with high CEC tend to have higher organic matter contents and nutrients due to the binding of cation nutrients such as nitrate (NH_4^+) and potassium (K^+); anion nutrient such as hydrogen phosphate (HPO_4^{2-}) by multivalent cations (Hamarashid, et al, 2010; Yaghi and Hartikainen, 2014). This has resulted in the reduction of nutrient leaching into the water pathway and increase in nutrient availability. A related study suggested that soil with application of clay significantly reduced NH_4^+–N leaching by 79% whereas K^+ leaching was reduced by 51% in the short term and 45% in the long term. Soil with high clay tended to remain stable in controlling NH_4^+–N leaching and K^+ leaching for 1.5 years (Besch *et al,* 2018). Besides, organic matters are increased by binding with clay by ligand exchange, weak Van der Waals forces and cation bridges (Von et al, 2006).

2.5 Conventional management of nutrient fixation problem

2.5.1 Over-application of fertiliser (N, P, and K)

Increased in fertiliser application has provided conventional farmers with favourable outcome in terms of the production and profit. It has also improved pest and disease control and prevent nutrient deficiency. However, the continuous input of fertiliser may result in rising of environmental and health concern. The leaching of nutrients to the water pathway can cause algae blooming and eutrophication (Ch'ng et al, 2014). This will cause the oxygen to be depleted and aquatic organisms become fatal. In this cases, P and N are the main nutrient limiting the growth of aquatic plants. Ammonium volatilisation and denitrification may cause return of N to the atmosphere and increase nitrous oxide formation which will deplete the ozone layer in the upper atmosphere (Newbould, 1989).

2.5.2 Liming

Liming application is an efficient way in regulating soil acidity particularly in tropical acid soil. Liming increases soil pH in highly acidic soil. It also reduces Al, Fe, Mg, and Mn toxicity presences in soil structure. It enhances the biological activities and stimulating biogeochemical cycle such as N and P cycle (Osman, 2013). Soil structure, soil porosity and soil aeration can be improved through lime application. According to Liao *et al* (2018), liming and rice straw retention tend to increase the rice production particularly in acid soil as they have increased soil N availability by enhancing N mineralisation rates, organic matter decomposition and soil enzyme activities in biogeochemical cycles. However, liming may not always be an environmentally friendly practice in fixing Al and Fe. Precipitation of Ca and P ions as calcium phosphate may occur if over liming takes place (Ch'ng et al, 2014). Osman (2013) reported that over liming may also causes P availability to decrease and micronutrients deficiencies.

2.5.3 Organic amendment

Organic amendment is the supplement of any organic matter to the soil to improve its physical, chemical and biological properties (Scotti et al, 2015). These days, the most common soil amendment applied are manure and compost which derived from agriculture waste. These organic amendments tend to improve the physical properties of soil which includes the soil structure, water holding capacity, water infiltration and soil aeration (Ch'ng et al, 2014; Scotti et al, 2015). Besides, they induce slow mineral nutrients release which reduce the risk of N, P and K leaching. Laird *et al* (2010) proved that organic amendment could contributed to the reduction of total N as well as total dissolved P losses by 11% and 69%, respectively. Other study done by Yao et al (2012) showed that organic amendment could contributed to the reduction of nitrate as well as ammonia by 34% and 14%, respectively. Mineralisation and decomposition of these amendments increase the mild organic acid in the soil such as humic acids which dissolve the compound of soil P and make it more available for plant uptake (Ch'ng et al, 2014; Scotti et al, 2015). According to Fleming *et al* (2010), the inherent N properties of rice straw amendment could the increase in total N in soil.

2.6 Agricultural waste

2.6.1 Definition of agricultural waste

Waste products either organic or inorganic wastes on farm through agricultural activities are known as agricultural wastes. The agricultural activities may include growing seed, dairy farming, livestock farming and horticulture (Geoffrey and Pablo, 2009). According to Ali *et al* (2017), agricultural waste is defined as accidental products produced from the agricultural crops. These waste products increase significantly each year.

2.6.2 Rice straw

Rice is the most important staple food. According to Norimah (2008), the consumption pattern of rice among the adult in Malaysia are about 2½ plates of rice per day. About 1.82 million tons of the rice are being produced in 2017 year to achieve the nation requirement (Abdul, 2017). This large number of rice production has indirectly contributed large number of paddy residues (rice husks and rice straws). In Malaysia, 0.48 million tonne of rice husk and 3, 176, 593.2 tonnes of rice straw are produced yearly. The cost to remove the rice straw after harvesting is very high, therefore, open-air burning of rice straws becomes common practice in Malaysia to eliminate such waste. This practice generates severe air pollution and produces large amount of greenhouse gas. Such wastes and carbon emission has raised the public concern in Malaysia. Taking into consideration about the issue of open burning of rice straw and leaching of conventional fertilisers, converting such waste into organic compost can be a desirable choice. These rice straw compost can reduce air pollution caused by air pollution and increase soil fertility at the same time.

2.7 Benefit of compost

Composts are defined as the decomposition of organic residues and used as fertilisers. Composting organic residues from farm like straw, food wastes, farm waste and tree leaves and applying them as organic fertilisers has become increasingly popular in Malaysia. Composts help in soil erosion control by preventing the formation of soil crusts due to their high-water retention ability, encourage percolation with their rough surfaces and reduce rain drops impact. Composts speed up vegetation by reducing evaporation and promote root growth as well as provide nutrients for vegetation cover (Faucette et al, 2004). According to Bilal, Thomas and Ezio (2016) composts improve stormwater quality particularly in disturbed soils. This is because composts aid in the soil restoration by reducing nutrient leaching. Composts consist of organic form of nutrient which are slowly mineralised and release at a slow rate suitable for plant uptake. Thus, they act as slow release fertilisers while reducing the leaching and denitrifying effects.

2.8 Potential of apply compost in soil nutrient – Fixing soils

Soil fertility is improved by compost application to the soil. Compost application reduce the over fertilisation problem such as leaching and P fixation. However, the direct effect of compost on soil fertility remain unclear. Some studies have found that compost application may not increase production and may even cause decrease in yields on the initial month. The reason is due to compost with high C/N ratio may encourage N immobilisation (Liao *et al*, 2018). As several studies have proved that long term compost application may lead to crop production increase because of improve of soil fertility and nutrient content. Compost has provided solution to nutrient losses by slow mineralisation and release nutrient at a slow rate suitable for plant uptake. Hence, leaching and denitrification of N and K is reduced. Besides, compost with mild organic acid dissolve the compound of P has made P more available plant uptake. Thus, the P fixation is solved.

2.9 Mechanism of compost in reducing soil problem

Compost consists of three fractions of materials which are humic acid, fulvic acid, and humin. (Osman, 2013) Humic acid and fulvic acids contain a variety of functional such as carboxyl and phenol. Adsorption for hydrophobic organic molecules, hydrophilic polar organic molecules and heavy metals (Al and Fe) take places due to the amphiphilic properties of humic acids (Chatterjee et al, 2013). Thus, this releases the P which are initially bounded to the soil surface. Besides, P can be readily absorbed by plant when the P compounds dissolved by mild organic acid on compost. Consequently, P fixation is solved.

2.9.1 Slow release fertilisers – direct supply of nutrient

Composts contain organic form of N and K which undergoes slow mineralisation in the soil to convert the organic nutrient to inorganic nutrient available for plant uptake. Compost act as slow release fertiliser as the released of N is relatively slow at 1-3% of total N/year (Ch'ng *et al*, 2015). This will in turn prevent the nutrient leaching causing eutrophication and reduce the denitrification of nutrient. Composts application increase nutrient supply by soil microbe activities through mineralisation process. Thus, the nutrients are constantly recycled and reused by plants with aid of nutrient fixing microorganisms. This statement was supported by Zhong (2009), rice straw amended soil had obviously increased the enzyme activities as well as altering the microbial activities which aids in mineralisation process. Relatively high K and P concentration in organic amendment might result higher available P and available K in the soil. Compost improves the soil fertility and nutrient replenishment which contribute to revegetation. According to Beesley *et al*, 2011, application of organic amendment has played an important role in remediation, revegetation and restoration of contaminated soils.

2.9.2 Increase in the soil pH

According to Mokolobate and Haynes (2003), composts possess liming effect on tropical acid soil due to their alkaline properties. Soil pH with lower than 6.5 may increase solubility of cations like Al and Fe in the soil while decrease Ca and Mg in the soil. Al and Fe highly predominant in tropical acid soil like Malaysia. These elements, however, are not essential elements for normal plant growth. In fact, they can cause toxicity to the plant. Compost application to the acid soil can reduce Al toxicity and reduce the requirement of conventional fertilisers. This is because the cations mentioned will bind to the functional group of compost which makes the nutrient more available for the plants (Havlin *et al*, 2005). According to Ch'ng (2014), basic cations like Na, Ca, K as well as Mg released from the rice straw amendment have caused the exchanged of protons between the rice straw amendment as well as the soil. This might cause an increased in soil pH.

Chapter 3

METHODOLOGY

3.1 Soil Sampling and Soil Preparation

The soil samples were taken at 0-20 cm from uncultivated land area in Agro Techni Park Universiti Malaysia Kelantan Jeli Campus. The total of 20 sacks of soil samples of soil samples were taken within a 50 m x 50 m randomly. The soil was air-dried, ground and sieve to pass through a 2-mm and 5-mm sieve, respectively for laboratory analysis and pot experiment.

3.2 Soil Analysis

Before the pot experiment was carried out, the soil was analysed for bulk density, soil texture, soil pH, total organic matter, total carbon, soil exchangeable Fe, soil exchangeable Fe, soil electrical conductivity (EC) and soil available N, P and K. The details of the analysis were as follows:

3.2.1 Bulk Density Determination

Soil bulk density was determined by using coring method (Dixon and Wisniewski, 1995). Coring was hammered into the soil to desired soil depth. Then, coring was removed from the soil carefully. The excess soils were trimmed. Soils with coring were weighed and put into the oven and dried at 105 °C until constant weigh was obtained. The bulk density was determined by the equation created by Dixon and Wisniewski (1995) as follows:

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

3.2.2 Soil Texture Determination

According to Bouyoucos (1962), soil texture was determined by using hydrometer method. A 50 g of soil sample was placed in a blender cup. Next, 4 M of NaOH was added into the blender cup to adjust the soil pH to pH 10. Distilled water was filled into the blender cup within 10 cm of the top rim. Then, the blender cup was placed on stirring machine and mixed for 15 minutes. The soil suspension was transferred into 1 L of measuring cylinder. Distilled water was added into the measuring up to 1130 mL. The soil suspension was stirred using a stirring rod for 40 seconds. Next, hydrometer was placed into the suspension and the meniscus on the hydrometer stem was recorded. The hydrometer was removed and rinsed. The soil suspension was stirred again and the second reading of the hydrometer was recorded. The result obtained for both readings were evaluated for the amount of silt and clay of the soil in grams of the sample. Lastly, the soil suspension was stirred again and third hydrometer reading was taken after 2 hours of settling time. The calculations for soil texture were as follows:

Percentage of sand + silt + clay = 100% (3.2)

For 40s reading:

Percentage of silt + clay = (a/50) x 100% = w (3.3)

Percentage of sand = (100-w) % = x (3.4)

After 2 hours reading:

Percentage of clay = (b/50) x 100% = y (3.5)

Percentage of silt = w-y = z (3.6)

3.2.3 Soil pH and Soil Electrical Conductivity (EC)

Soil pH and EC were determined by potentiometric method. In this method, a ratio of 1: 2.5 (soil and distilled water suspension) was used to measure soil pH and EC by using digital pH meter and EC meter, respectively. (Peech, 1965). First, 12.5 ml of distilled water with 5 g of air-dried soil were added in beaker at a ratio of 1:2.5 and the procedure was repeated for 3 samples. The samples were shaken at 180 rpm for 15 minutes by using an orbital shaker. Then, the samples were left overnight for 24 hours before using a digital pH meter for pH determination and EC meter for EC determination.

3.2.4 Soil Total Organic Matter and Total C Determination

Soil total organic matter and total C were determined using combustion method (Tan, 2003). The air-dried sample was placed in an oven and was left for 24 hours at 60 °C. The sample was then being cooled down using a dessicator. Initial weight of crucible was recorded. Then, the weight of crucible was filled with 5 g of air-dried soil. Next, the sample was ashed at 300 °C in the muffle furnace for an hour and the temperature was increased to 550°C. The ashing process was continued for another 8 hours. Lastly the sample was allowed to cool before inspection. The weight of sample in the crucible was calculated. The total organic matter and C were calculated using the following equations (Tan, 2003):

$$\text{Total OM} = \frac{\text{Initial weight of soil sample(g)} - \text{final weight of soil sample (g)}}{\text{Initial weight of soil sample(g)}} \times 100\% = x \quad (3.7)$$

$$\text{Total C} = x \text{ x } 0.58 \quad (3.8)$$

3.2.5 Soil Exchangeable Acidity and Exchangeable Aluminium

The soil exchangeable acidity and exchangeable Al were determined by using titration method (Rowel, 1994). A 10 g of soil and 30 mL of 1 M KCl were placed into a beaker and left overnight for 24 hours. After 24 hours, the sample was filtered with Whatman Filter Paper No. 2 into 100 mL volumetric flask and the volume was made up to the mark. Next, 50 mL of soil extract was pipetted into 250 mL conical flask. A total of 5 drops of phenolphthalein was added as indicator. The solution was titrated against 0.01 M NaOH until pink colour appeared. This measured the soil exchangeable acidity. The solution was then titrated against 0.01 M HCl until the solution become colourless as this measured the soil exchangeable Al. The soil exchangeable acidity and soil exchangeable Al were calculated by using the following equations (Rowel, 1994):

Exchangeable acidity (cmol kg^{-1}) = $\frac{[0.2 \times Titraet\ volume\ of\ 0.01\ M\ NaOH \times 10]}{soil\ mass\ (g)}$ (3.9)

Exchangeable Al (cmol kg^{-1}) = $\frac{[0.2 \times Titraet\ volume\ of\ 0.01\ M\ HCl \times 10]}{soil\ mass\ (g)}$ (3.10)

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

Soil extractable K, Ca, Mg, Na, Cu, Zn, and Fe were extracted using the Mehlich No. 1 Double Acid method (Mehlich, 1953). A 4 mL of concentrated HCl and 0.7 mL of concentrated H_2SO_4 were pipetted into a 1,000 mL volumetric flask and the volume was made up to volume. A 5 g of soil samples were weighed and placed into a 50 mL beaker. After that, 25 mL of the extraction reagent was added and the solution was shaken for about 10 minutes on a reciprocal shaker. Next, the supernatant was filtered into another beaker using Whatman Filter Paper No. 2, and the extract was collected. Atomic Absorption Spectrometer (AAS) was calibrated and the extract was aspirated into AAS and the reading was recorded. The soil exchangeable cations were calculated using the following equation (Mehlich, 1953):

Soil exchangeable cation (ppm) = AAS reading (ppm) x ($\frac{Volume\ of\ extractant\ (mL)}{weight\ of\ soil}$)(3.11)

3.2.7 Soil Available P Determination

Mechlich No.1 Double Acid Method was used to extract the soil available P (Mechlich, 1953). A 4 mL of concentrated HCl and 0.7 mL of concentrated H_2SO_4 were pipetted into a 1,000 mL volumetric flask and the volume was made up to volume. A 5 g of sample was weighted and placed into a 50 mL beaker. After that, 25 mL of extraction reagent was added. Then, the solution was shaken for 10 minutes on a reciprocal shaker. Next, the supernatant was filtered into plastic vials using Whatman Filter Paper No. 2 and the P extract was collected. The solution was analysed by the molybdenum blue method (Murphy and Riley, 1962) and the developed blue colour was analysed by UV spectrophotometer at 882 nm wavelength.

3.2.8 Soil Total N

According to Bremner and Lee (1940), Kjeldahl Method was used to determine the total N. A 0.5 g of soil sample was weighed and sieved through 0.5 mm into 50 ml of Kjeldahl digestion tubes. A few drops of distilled water were added to the soil follow by 5 mL of concentrated sulphuric acid. A 1 g of Kjehdahl catalyst were added. The mixtures were shaken for 30 minutes to allow equilibrium. The mixtures were heated in a digestion block at 400 °C for 1 hour until it became colourless. The sample was later allowed to cool down by adding 30 mL of distilled water to the sample. The residues of sand in Kjeldahl flask was made up to 100 mL in a 100 mL of volumetric flask. A 10 mL of sample was pipetted into distillation apparatus and 10 mL of 2% boric acid indicator solution. A 10 mL of 40% NaOH was added to the distillation apparatus. The colour changed from purple to green during distillation. Some volume of the distillate in the conical flask was removed to get twice the original volume (20 mL). The sample was titrated with 0.01 M H_2SO_4 until the colour change back from green to purple. The percentage of nitrogen in the soil was calculated as follow:

Nitrogen, % = [(V-B) x M x R x 14.01 / Wt x 1000] x 100

Where: V = Volume of 0.01 M HCl that was titrated for the sample (mL)

B = Digested blank titration volume (mL) M = Molarity of HCl solution

14.01 = Atomic weight of N

3.3 Compost Preparation

The rice straw composts were prepared from the mixture of rice straws, goat manures, molasses as well as chicken feeds. The rice straws were taken from a paddy field at Pasir Puteh, Kelantan, Malaysia. These rice straws were later bulked, air dried, and shredded. The sampling of goat manure was acquired from a dairy farm located in Kemahang, Kelantan. The composting process was carried out at an open space of research area in Universiti Malaysia Kelantan, Jeli Campus, Malaysia. The 3 composting containers with 435 mm (height) x 425 mm (base) were prepared for composting purposes. The 12 holes were made with a hole size 0.5 cm diameter, respectively. The rice straw compost was made by the mixture of 80% shredded rice straw + 10% of goat manure slurry +5% of chicken feed + 5% of molasses in composting container. The preparation of rice straw compost was referred on the formulation ratio done by Ch'ng *et al*. (2013). The composting processes were repeated for 3 replications and it took 60 days for maturation.

3.3.1 Compost Characterisation

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

3.3.2 Total P, K, Ca, Mg, Na, Cu, Zn, and Fe determination

Single Dry Ashing method was used to extract the Total P and K in the compost (Jones, Uwah, Iren and Mills, 1991). A 1 g of ground and dried sample was weighed and placed into crucible. The sample was placed in a muffle furnace and initially ashed at 300 °C for 1 hour. The temperature of the muffle furnace was raised to 520 °C after 1 hour and was ashing for another. The sample was cooled in a desiccator. Then, the sample was added with few drops of distilled water followed by 2 mL of concentrated HCl. The sample was evaporated to dryness in the fume chamber using hot plate. After then 10 mL of 20% HNO_3 was added to the sample and was heat for another 1 hour. The sample was filtered through Whatman Filter Paper No. 2 into 100 mL volumetric flask and was made up to the volume. As for K, Ca, Mg, Na, Cu, Zn, and Fe determination, the sample was aspirated into AAS and the absorbance reading was taken. Molybdenum blue method (Murphy and Riley, 1962) was used to determine the total P in the compost. The blue colour was analysed using UV spectrometer (Thermo Fisher Scientific model 4001/4) at 882 nm wavelength.

3.4 Pot experiment and Treatments

A pot experiment was conducted in a net house in University Malaysia Kelantan Jeli Campus. A total of 18 pots were filled with 7 kg of soil which was sieved with 5 mm sieve. The test crop used in this pot experiment was *Zea mays L* hybrid sweet corn 801. The cultivation of *Zea mays L.* in the pot experiment was supplied with N, P, and K fertiliser to ensure optimum growth of corns. Urea (46% N), Christmas Island Rock Phosphate (CIRP) (30% P_2O_5) and Muriate of Potash (MOP) (60% K_2O) and each of them was applied at 60 kg N ha^{-1} (130 kg N ha^{-1} Urea), 60 kg P_2O_5 ha^{-1} (200 kg CIRP ha^{-1}) and 40 kg K_2O ha^{-1} (67 kg MOP ha^{-1}) rate based on MARDI's recommendation. The amount of rice straw compost applied was varies based on the treatment listed in Table 3.1 (John *et al*, 2013; Malaysia Agricultural Research and Development Institute (MARDI), 1993. These fertilisers were added on 10th day of sowing and 28th day of planting (DAP) by equal splits. The experimental design used in this study was completely randomized design (CRD) with 3 times replication.

Table 3.1: List of treatments in pot experiment

Treatment Numbers	Treatment
T0	Without Fertilizer (Serves as a negative control, without any application of chemical fertilizer and rice straw compost)
T1	130 kg Urea ha^{-1} + 200 kg CIRP ha^{-1} + 67 kg MOP ha^{-1} (Serves as a positive control, application of chemical fertilisers (Urea, CIRP, and MOP) only without rice straw compost)
T2	130 kg Urea ha^{-1} + 200 kg CIRP ha^{-1} + 67 kg MOP ha^{-1}+ 5 t ha^{-1} Compost (Application of chemical chemical fertilisers (Urea, CIRP, and MOP) with rice straw compost to evaluate the potential of rice straw compost in improving the soil N, P, and K availability and total N, P, and K uptake)
T3	130 kg Urea ha^{-1} + 200 kg CIRP ha^{-1} + 67 kg MOP ha^{-1}+ 10 t ha^{-1} Compost (Application of chemical chemical fertilisers (Urea, CIRP, and MOP) with rice straw compost to evaluate the potential of rice straw compost in improving the soil N, P, and K availability and total N, P, and K uptake)
T4	130 kg Urea ha^{-1} + 200 kg CIRP ha^{-1} + 67 kg MOP ha^{-1}+ 15 t ha^{-1} Compost (Application of chemical chemical fertilisers (Urea, CIRP, and MOP) with rice straw compost to evaluate the potential of rice straw compost in improving the soil N, P, and K availability and total N, P, and K uptake)
T5	130 kg Urea ha^{-1} + 200 kg CIRP ha^{-1} + 67 kg MOP ha^{-1}+ 20 t ha^{-1} Compost (Application of chemical chemical fertilisers (Urea, CIRP, and MOP) with rice straw compost to evaluate the potential of rice straw compost in improving the soil N, P, and K availability and total N, P, and K uptake)

3.5 Post-treatment Soil Analysis

The soil samples were collected during the tasselling stage, which was on 60 DAP. The soil sample were collected, air-dried, crushed and sieved using 2-mm sieve. After that, the soil samples were analysed for soil pH, total OM, total C, soil exchangeable Al, soil exchangeable Fe, soil electrical conductivity (EC) and soil available N, P and K by using the mentioned method.

3.5.1 Plant growth parameters of *Zea mays* measurement

Plant length, number of leaves, leaf area index, leaf area ratio, and root length were measured at 60 DAP. Leaf area index was calculated using the following formula (Aldesuquy *et al*, 2014):

$$\text{Leaf area} = \text{Length} \times \text{Breadth} \times 0.75$$

3.5.2 Plant Tissue Analysis

The plants in pot experiment were harvested and partitioned into leaves, stem, and roots. They were then separated at 60 DAP for plant tissues analysis. For plant tissue analysis, single dry ashing method was used in order to extract total N, P, and K in the plant tissues (leaves, stems and roots) (Tan,2003). The procedure was similar to the mentioned procedures in section 3.3.1 and 3.3.2. The concentration of N, P, and K in the leaves, stems and roots were multiplied by respective dry weight to obtain the amount of N, P and K uptake by plants.

3.5.3 Nutrient uptake

According to Pomarces and Pratt (1987), N, P, and K uptake were determined by the following equation:

Nutrient uptake

Uptake = Concentration x Dry weight (g)

3.6 Statistical Analysis

The data in this study was analysed using Statistic Package for Social Science (SPSS 21.0). The Analysis of Variance (ANOVA) was used to detect the treatment effects while Tukey's test was used to separate the treatment means at $p \leq 0.05$.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Characteristics of Soil Samples and Rice Straw Compost

The selected physicochemical properties of soil in in Rengam Series (*Typic Paleudult*) were shown in Table 4.1. The soil was a sandy clay loam with a pH of 5.19. The low soil pH contributed to high concentrations of Al and Fe (Ch'ng *et al*, 2015). The total organic matter, C and N in the soil were relatively low due to the high percentage of sand which caused little capacity to hold these nutrients (Osman, 2013). Low soil available P could be attributed to the high concentration of Al and Fe in the soil (McBride, 2000).

Table 4.1: Selected physico-chemical properties of soil.

Property	Value Obtained	Property	Value Obtained
Bulk density (g cm^{-3})	1.03	Available P (ppm)	0.81
Soil texture	Sand: 75%	Exchangeable acidity (cmol kg^{-1})	0.57
	Clay: 24%	Exchangeable Al (cmol kg^{-1})	1.23
	Silt: 1% (Sandy clay loam)	Exchangeable K (ppm)	180.16
pH (water)	5.19	Exchangeable Ca (ppm)	959.2
Total organic matter (%)	3.36	Exchangeable Mg (ppm)	1,774.13
Total C (%)	1.95	Exchangeable Fe (ppm)	186.44
Total N (%)	0.03	Exchangeable Zn (ppm)	0.85

The total N, P, and K of the rice straw compost were 2.14%, 0.34%, and, 8.71%, respectively (Table 4.2). The C/N ratio of the composts were 19.92 whereas the C/P ratio was 125.38. These ratios indicate the net mineralisation of the rice straw compost. The pH, EC, C, Ca, Mg, Na, Zn, and Cu of the compost were 7.55, 1.53 dS m^{-1}, 42.63%, 0.55%, 0.345%, 10.6%, 54.2 µg/g and 8 µg, respectively (Table 4.2).

Table 4.2: Selected chemical properties of rice straw compost.

Property	Rice straw compost
pH	7.55
Electrical conductivity (dS m^{-1})	1.53
Total organic matter (%)	73.53
Total C (%)	42.63
Total N (%)	2.14
Total P (%)	0.34
C/N ratio	19.92
C/P ratio	125.38
Total K (%)	8.71
Total Ca (%)	0.55
Total Mg (%)	0.345
Total Na (%)	10.6
Total Zn (µg/g)	54.2
Total Cu (µg/g)	8
Total Fe (µg/g)	1,362.40

4.2 Effect of Treatment on Selected Chemical Properties of Soil At 60 DAP

The selected chemical properties of soil pH, EC, total organic matter, total carbon, total N, exchangeable Acidity, exchangeable Al, available P, exchangeable K, exchangeable Ca, exchangeable Mg, and exchangeable Fe which was affected by the application of compost was summarized in Table 4.3. At 60 DAP, the treatment with compost (T2, T3, T4, and T5) showed higher soil pH compared to the T0 and treatment with chemical fertiliser only, T1 (Table 4.3(a)). Soil pH was significantly increased with the increase in application rate of rice straw compost. The increases in soil pH can be attributed to the H^+ consumption capacity of organic materials (Stevenson and Vance, 1989). Highly decomposed rice straw compost consisted of humic and fulvic acids. These acids possessed a carboxyl group which allowed it to consume H^+ as well as Al (Havlin *et al*, 2005). This might help in increasing the soil pH and decreased the Al concentration. According to Ch'ng *et al* (2014), basic cations like Na, Ca, K as well as Mg released from the rice straw amendment have caused the exchanged of protons between the rice straw amendment as well as the soil. This might cause an increased in the soil pH. In this study, T1 had a higher pH compared to T0 due to types as well as different composition of fertiliser which resulted in the increase in soil pH (Bom, 2018).

At day 60 DAP, the treatment with compost application (T2, T3, T4 and T5) showed higher EC compared to treatment without compost (T0 and T1) (Table 4.3(a)). This was resulted from the salinity of rice straw compost. The salinity of rice straw compost comes from the Ca and Mg content in it (Hamed, 2011) (Table 4.2). At 60 DAP, T4 and T5 showed the most significant increase in EC due to more basic cations were added to the soil during fertilization (Zhao et al, 2017).

Table 4.3(a) Effect of Treatment on Selected Chemical Properties of Soil At 60 DAP

Treatment	pH (water)	EC	Total organic matter	Total C	Total N	Exchangeable acidity	Exchangeable Al
		(dS m^{-1})	(%)	(%)	(%)	(cmol kg^{-1})	
T0	5.28± 0.06d	0.12 ± 0.02 d	7.47 ± 0.09 c	4.33 ± 0.05 b	0.06 ± 0.003 c	1.13 ± 0.03 d	0.92 ± 0.21 c
T1	6.12± 0.01c	0.30 ± 0.03 c	7.63 ± 0.09 c	4.43 ± 0.05 b	0.06 ± 0.003 c	0.98 ± 0.01 d	0.99 ± 0.12 c
T2	6.32± 0.01b	0.48 ± 0.04 b	9.60 ± 0.23 b	4.67 ± 0.91 b	0.08 ± 0.003 b	0.67 ± 0.07 c	0.64 ± 0.06 bc
T3	6.46± 0.01b	0.59 ± 0.02 b	11.07 ± 0.98 b	6.42 ± 0.57 a	0.08 ± 0.003 b	0.46 ± 0.02 b	0.42 ± 0.06 ab
T4	6.60± 0.02a	0.76 ± 0.003 a	11.27 ± 1.00 b	6.53 ± 0.58 a	0.09 ± 0.010 b	0.17 ± 0.01 a	0.23 ± 0.11 a
T5	6.63± 0.03a	0.76 ± 0.01 a	13.33 ± 0.24 a	7.73 ± 0.14 a	0.11 ± 0.000 a	0.14 ± 0.04 a	0.21 ± 0.04 a

Different letters within a column indicate significant difference between means using Tukey's test $P \leq 0.05$

Similarly, applying the compost (T2, T3, T4 and T5) showed a significant increase in the soil total N and exchangeable K compared to the T0 and T1 (Table 4.3(a)(b)). Total N, available P, exchangeable K, exchangeable Ca, and exchangeable Mg increased with the increasing in application level of rice straw compost for each treatment. High total N and exchangeable K in the soil after compost application was due to compost derived from rice straw that contained negatively charged humic and fulvic acids which might contribute to the increase in CEC (Fleming et al., 2013). Thus, cation like K^+ and NH_4^+ are likely to adhere to the rice straw compost. Therefore, N and K deficiency are less likely to happen in the soil due to denitrification and volatilisation process. According to Laird et al (2010), the increase in total N in soil could also be attributed to the inherent N properties of rice straw amendment. In the same study also proved that organic amendment could contributed to the reduction of total N as well as available P losses by 11% and 69%, respectively. Other study done by Yao et al (2012) showed that organic amendment could contributed to the reduction of nitrate as well as ammonia by 34% and 14%, respectively.

Soil with rice straw amendment (T2, T3, T4, and T5) had a significant increase in the soil exchangeable Na, Ca, and Mg concentration (Table 4.3 (b)) compared to those with nonamended soil (T0 and T1) due to the inherent Na, Ca, and Mg in rice straw compost (Ch'ng, 2015). These basic cations like Na, Ca, K as well as Mg released from the rice straw amendment had indirectly increased in soil available P which act as a liming effect in acid soils. Phosphorus which were initially bound by the Al and Fe were then free from the soil (Liao *et al*, 2018). According to Zhong (2009), rice straw amended soil had obviously increased the enzyme activities as well as altering the microbial activities. Relatively high K and P concentration in organic amendment might result higher available P and available K in the soil.

Exchangeable acidity, exchangeable Al^{3+}, and exchangeable Fe showed a significant decrease with the increase of application rate of compost for each treatment at 60 DAP (Table 4.3(a)(b)). Higher application rates of rice straw compost (T3, T4, and T5) decreased the concentration of trace element more significantly (Jones, 2016). Application of organic amendment reduced the exchangeable fractions in the soil due to the increased in cation exchange capacity (CEC) and the adsorption of Al by rice straw compost complexation sites, resulting in the dissolution of aluminium hydroxide (Fleming et al.,2013). Adsorption of Al cause the released of a reasonable amount in oxygen-containing surface functional groups (carboxyl, hydroxyl and phenolic) (Tong, 2011). Treatment with inorganic fertilizers alone, T1, had the highest exchangeable Al^{3+} and exchangeable Fe due to the chance for Triple Superphosphate (TSP) to release Fe into the soil (Ch'ng et al, 2014).

Table 4.3(b) Effect of Treatment on Selected Chemical Properties of Soil At 60 DAP

Available P	Exchangeable K	Exchangeable Ca	Exchangeable Mg	Exchangeable Fe
ppm	mg/L			
29.61 ± 4.98 c	639.33 ± 158.48 c	1,329.00 ± 56.36 bc	2,570.33 ± 192.07 c	358.33 ± 50.08 b
14.59 ± 0.50 c	431.33 ± 168.54 c	711.00 ± 304.85 c	2,360.33 ± 180.92 c	524.00 ± 56.13 c
52.46 ± 12.39 c	1,255.00 ± 170.32 bc	1,565.67 ± 62.33 bc	4,319.33 ± 665.68 b	359.00 ± 20.78 b
305.54 ± 49.60 ab	1,526.67 ± 115.15 b	1,709.67 ± 24.17 b	5,792.00 ± 107.25 b	220.67 ± 29.81 a
282.73 ± 30.95 b	3,672.00 ± 333.26 a	2,779.67 ± 492.48 a	9,074.67 ± 201.86 a	204.33 ± 22.19 a
370.867 ± 6.27 a	4,479.33 ± 457.32 a	3,508.33 ± 287.91 a	9,456.00 ± 260.83 a	148.67 ± 12.17 a

Different letters within a column indicate significant difference between means using Tukey's test P ≤ 0.05

4.3 Effect of Treatments on Selected Plant Growth Parameters (Number of leaves, Leaves length, Leaves Width, Root length, and Leaf area)

Effect of treatments on selected plant growth parameters (number of leaves, plant height, leaves length, leaves width, root length, and leaf area) were summarized in Table 4.4. Applying the compost (T2, T3, T4 and T5) caused significant higher number of leaves compared to nonorganic amendments (T0 and T1). Similarly, differences were observed with respect to the leaf's length, leaves width and root length at 60 DAP. Data recorded at 60 DAP revealed significantly larger leaves area on rice straw amended plants (T2, T3, T4 and T5) than those plants developed on nonamended pots (T0 and T1).

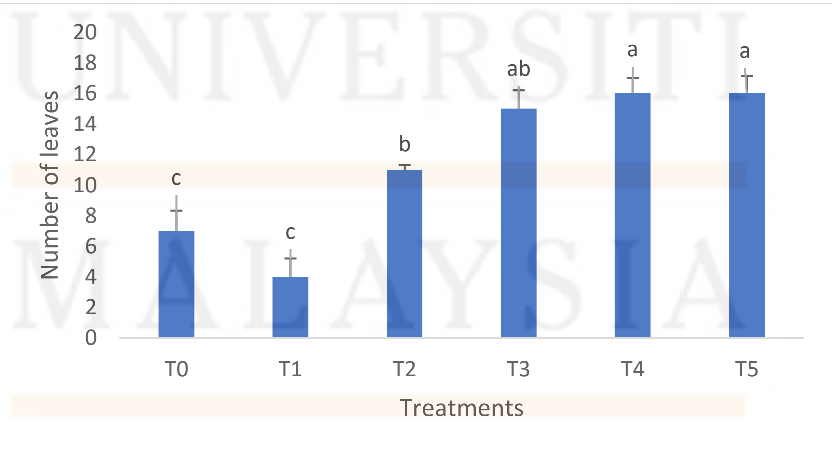
Table 4.4: Effect of Treatment on Selected Plant Growth Parameters (Number of leaves, Plant height, Leaves length, Leaves Width, Root length, and Leaf area)

Treatments	Number of leaves	Plant height	Leaves length	Leaves width	Root length	Leaf area
			(cm)			(cm^2)
T0	7 ± 1.33 c	38.7 ± 8.19 b	45.9 ± 10.29 c	2.2 ± 0.52 b	49.4 ± 3.67 b	82.5 ± 36.54 c
T1	4 ± 1.20 c	17.3 ± 2.67 b	24.1 ± 4.08 c	1.6 ± 0.23 b	35.3 ± 4.07 c	30.5 ± 9.08 c
T2	11 ± 0.33 b	147.0 ± 13.86 a	79.2 ± 0.66 b	4.4 ± 0.49 a	45.1 ± 2.54 b	261.9 ± 26.85 b
T3	15 ± 1.20 ab	167.3 ± 1.45 a	96.4 ± 3.51 ab	5.6 ± 0.17 a	78.2 ± 3.44 a	406.8 ± 20.77 a
T4	16 ± 1.00 a	173.3 ± 11.46 a	105.3 ± 6.24 a	6.4 ± 0.35 a	55.5 ± 7.43 b	497.9 ± 20.53 a
T5	16 ± 1.15 a	164.0 ± 32.97 a	109.8 ± 1.47 a	5.8 ± 0.70 a	56.8 ± 0.20 b	477.8 ± 62.32 a

Different letters within a column indicate significant difference between means using Tukey's test $P \leq 0.05$

4.3.1 Effect of Treatments on Number of leaves

Effect of treatments on number of leaves was shown in Figure 4.3.1. Significant differences in number of leaves of F1 hybrid sweet corn 801 variety. The plant growth parameters studies agreed with the hypothesis that amended chemical fertiliser with rice straw compost promoted the plant growth. Applying the compost (T2, T3, T4 and T5) caused significant increase in the on number of leaves compared to nonorganic amendments (T0 and T1). Plants treated with treatments 15 t ha^{-1} and 20 t ha^{-1} of compost, (T4 and T5) produced the largest number of leaves among all the rice straw amended (T2 and T3) and nonamended plants (T0 and T1). Leaves numbers were stimulated up to 4-fold with rice straw compost (T4 and T5) compared to non-amended plant, T1 and up to 2-fold compare with the control T0. The higher number of leaves on the organic amended plant might due to availability of nutrients during maize growth period. Similar results were reported by Laekemariam and Gidago (2013) where plant with integrated organic and inorganic fertiliser had significant effect on number of leaves per plant. Makinde (2007) and Rajeshwari et al. (2007) also showed that the positive effect on number of leaves per plants was closely related to the increased in application rate.

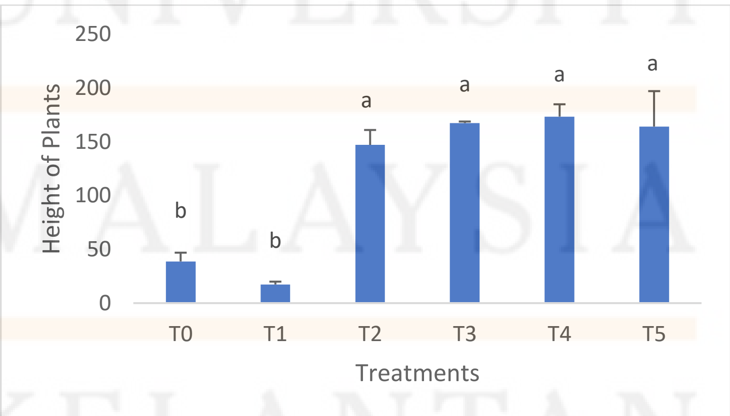


Different letters within a column indicate significant difference between means using Tukey's test $P \leq 0.05$

Figure 4.3.1: Effect of Treatment on leaves number of F1 hybrid sweet corn 801 variety at 60 DAP

4.3.2 Effect of Treatment on Plant Height

Significant differences were observed between applied and non-applieded F1 hybrid sweet corn 801 variety for height. Maize height at 60 DAP was greater in soils amended with rice straw compost (T2, T3, T4, and T5) (Figure 4.3.2). Plants treated with rice straw amended (T2, T3, T4, and T5) improved plant height by around 135 cm. Plant height were significantly reduced in non-amended plant (T0 and T1) compared to the rice straw amended plant. Non-amended plant T0 was higher plant height compare to chemical amended plant (T1). All rice straw amendments enhanced maize growth relative to the non-amended plants. The results obtained was supported by Ahmed *et al*. (2007), Makinde (2007), Rajeshwari et al. (2007), and Ayoola and Makinde (2009) on the sorghum. Enhancing plant growth in acidic soils with rice straw amendment might result in a decrease of Al and Fe availability in the soil, the enhanced the soil nutrients (N, P and K), and nutrient uptake by plants (Jones et al, 2016). This positive effect on plant height could also attribute to the nutrient loading of the rice straw compost (Kammann *et al*, 2015). The minimum plant height during 60 DAP (17.3 cm) was recorded from T1. This finding was supported by Pan *et al* (2018) on wheat growth. Pan stated that the drastic immobilisation of chemical fertiliser during plant growth might cause a significant decreased in plant nutrient availability.



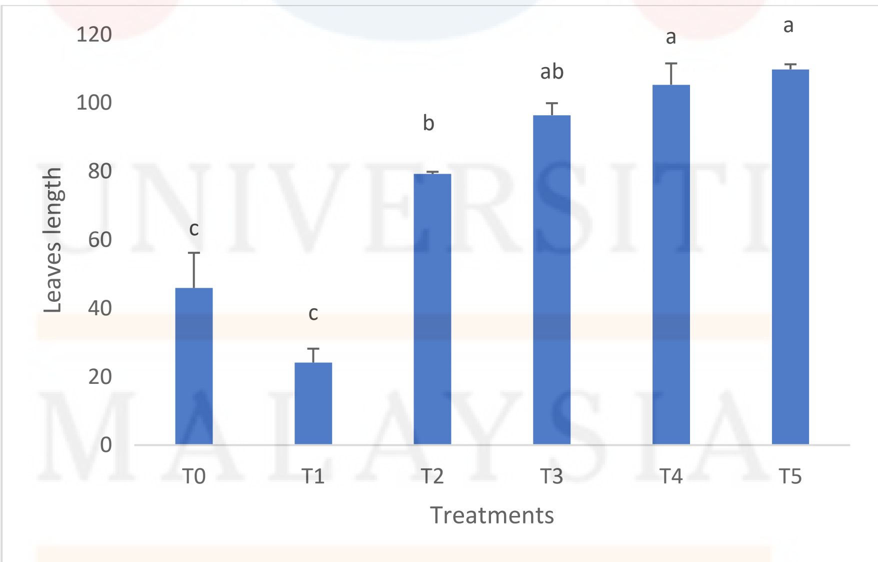
Different letters within a column indicate significant difference between means using Tukey's test P ≤ 0.05

Figure 4.3.2: Effect of Treatment on Plant Height of F1 hybrid sweet corn 801 variety at 60 DAP

4.3.3 Effect of Treatment on Leaves Length and Leaves width

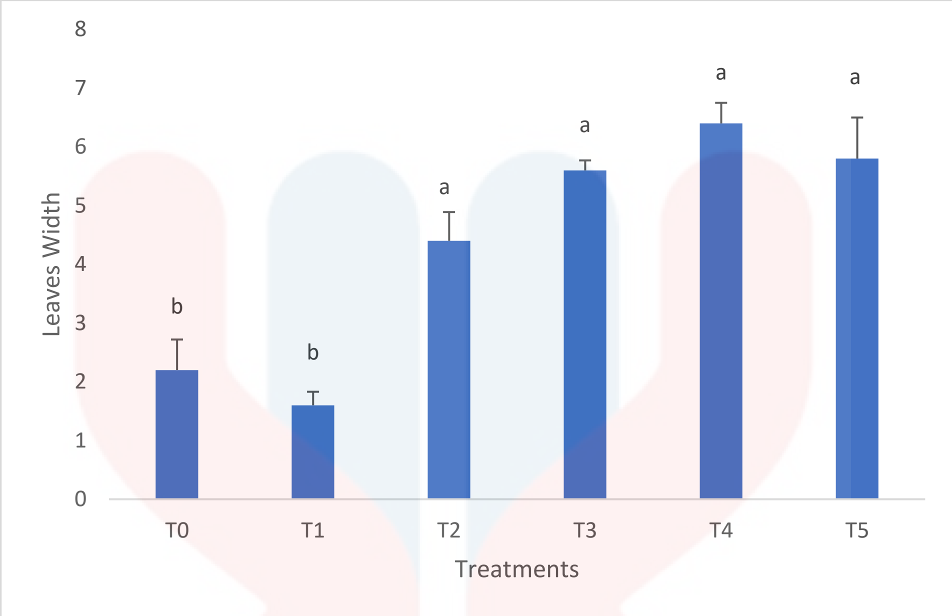
Effect of Treatment on leaves length was shown in Fig 4.3.3 (a). significant differences in leaves length of F1 hybrid sweet corn 801 variety. The plants with rice straw compost (T2, T3, T4, and T5) showed a significantly increased in the leaf's length compared to the non-amended plants (T0 and T1). Plants treated with treatments T2 produced less significance in leaf's length compared to the other rice straw amended plants (T3, T4 and T5).

Effect of Treatment on leaves width was shown in Fig 4.3.3 (b) significant differences in leaves width of F1 hybrid sweet corn 801 variety. The plants with rice straw amended (T2, T3, T4, and T5) showed a significantly increased in the leaf's width compared to the non-amended plants (T0 and T1). Plants treated with treatments (T0 and T1) produced smaller leaves compared to rice straw amended plants (T2, T3, T4, and T5). T4 produced the largest leaves among the others.



Different letters within a column indicate significant difference between means using Tukey's test P ≤ 0.05

Figure 4.3.3 (a): Effect of Treatment on Leaves Length of F1 hybrid sweet corn 801 variety at 60 DAP

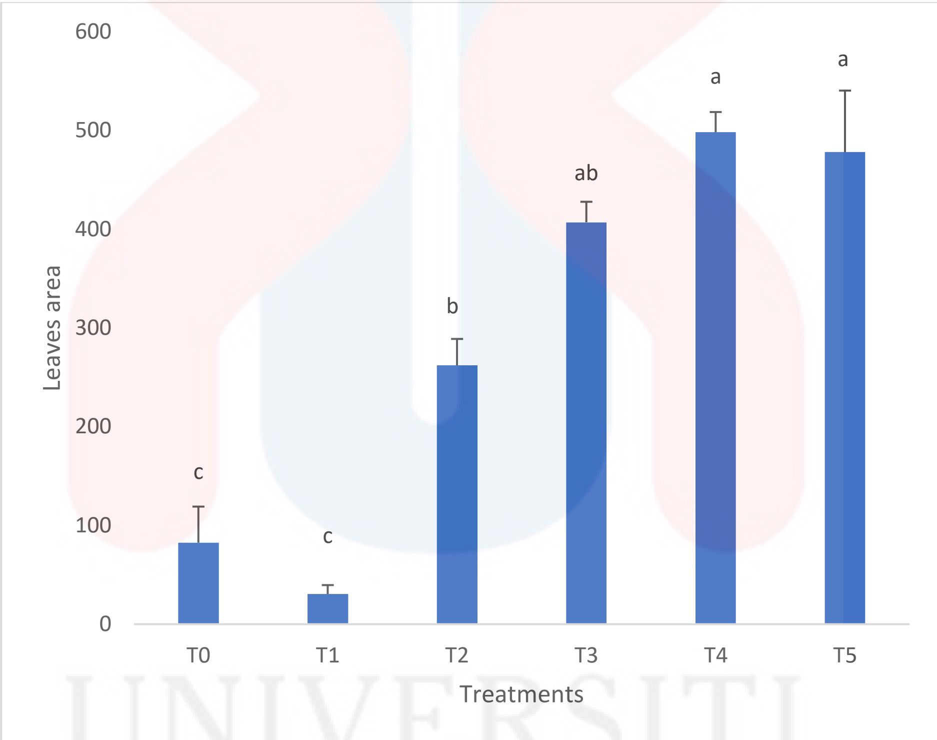


Different letters within a column indicate significant difference between means using Tukey's test $P \leq 0.05$

Figure 4.3.3 (b): Effect of Treatment on leaves width of F1 hybrid sweet corn 801 variety at 60 DAP

4.3.4 Effect of Treatment on Leaves Area

Leaves area is defined as the product of leaves width and leaves length. It is also defined as the measurement of size of assimilatory system of a plant (Laekemariam and Gidago, 2013). Leaf area index is important in determining the dry matter production and grain yield (Laekemariam and Gidago, 2013). Rice straw amendment application was closely related to the leaf area index. Effect of Treatments on leaves area was shown in Figure 4.3.4. Significant differences in leaves area of F1 hybrid sweet corn 801 variety. The plants with rice straw compost (T2, T3, T4, and T5) showed a significantly increase in the leaf's area compared to the non-amended plants (T0 and T1). Plants treated with treatments 10 t ha^{-1} of compost, T2, produced less significance in leaf's area compared to the other rice straw amended plants (T3, T4 and T5). T0 and T1 showed the least significant in leaf area among all the treatments. Higher leaf area index was closely related to the number of leaves per plant and dry weight of plant. According to Anamika *et al* (2017), organic amendment contained beneficial microbes and enhanced soil fertility by slow mineralisation of organic bound nutrients. This has increased the nutrient availability for plant uptake and stimulated photosynthetic ability of plants, especially in terms of carotenoid content Anamika *et al* (2017). As a result, rice straw compost applied significantly increased the leaves area and dry weight. This finding was supported by Makinde (2007), Rajeshwari et al. (2007) and Laekemariam and Gidago (2012) on maize. The T4 had the largest leaf area (497.9 cm^2) among all the treatments.

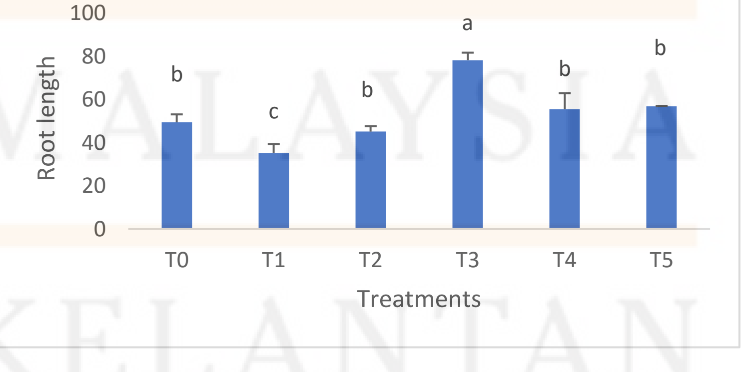


Different letters within a column indicate significant difference between means using Tukey's test $P \leq 0.05$

Figure 4.3.4: Effect of Treatment on leaves area of F1 hybrid sweet corn 801 variety at 60 DAP

4.3.5 Effect of Treatments on Root Length

Effect of treatments on leaves length was shown in Fig 4.3.5. Differences were not significant between the rice straw amended plants (T2, T4 and T5) and nonamended plant, T0. However, plants treated with rice straw amended, T3 showed the most pronounced effect compared to the others which produced the longest root length. Significant differences were observed from between treated and solely chemical fertiliser applied, T1. The T1 had the shortest root length among the different treatments. Such stimulating effect of rice straw compost was closely related to the physicochemical properties of amended soil as well as fulvic and humic aicds in the rice straw compost (Baldi and Toselli, 2013). Fulvic and humic aicds increased auxin production which resulted in significantly growth in root length (Trevisan *et al*, 2010). Besides, Baldi and Toselli (2013) reported that these mild acids would increase the rate of decomposition of rice straw compost. According to Herencia *et al* (2011), soil organic matter amendment increased soil porosity while decreased in soil bulk density. This statement was supported by Vignozzi *et al* (2005) where organic amendment increased soil porosity ranging from 16-20%. The T3 has the most pronounced effect on root length (78.2 cm). This result was similar to the previous research on peach root production (Baldi *et al*, 2010) where 10 t/ha of compost applied produced longest root length at 61-80 cm.



Different letters within a column indicate significant difference between means using Tukey's test P ≤ 0.05

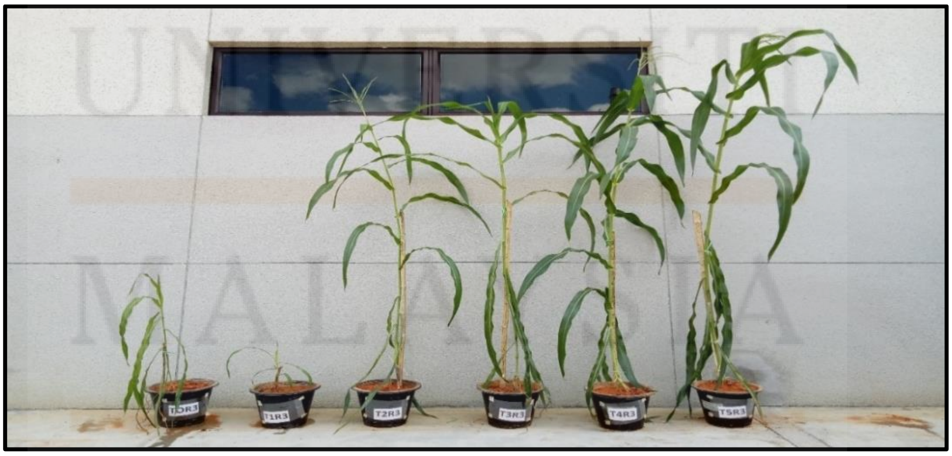
Figure 4.3.5: Effect of Treatment on Root Length of F1 hybrid sweet corn 801 variety at 60 DAP

4.4 Effect of Treatments on Physical Plant Growth Performance

Effect of treatments on plant height was summarized in Table 4.4. Differences were observed with respect to plant growth performances of maize in R1 (Fig. 4.4(a)). Data obtained at 60 DAP showed a significant higher maize plant amended with rice straw composts (T2, T3, T4 and T5) compared with maize grown on a nonamended pots (T0 and T1). Figure 4.4 (b) showed the growth responses of maize for second replication (R2). Similarly, the differences between the non-amended (T0 and T1) and rice straw compost amended pots (T2, T3, T4 and T5) were significant. The plant growth response increased with the increasing in application level for each treatment, with respect to the result showed in Table 4.3. Figure 4.4 (c) showed the growth responses of maize for third replication (R3). Again, maize with rice straw compost amended pots (T2, T3, T4 and T5) showed the most pronounced effect compared to nonamended pots (T0 and T1). In this case, the number of leaves increased with the increasing in application level. The leaves area also showed a significance increased with the increasing in application level of compost. The result obtained was supported by Ahmed et al. (2007), Makinde (2007), Rajeshwari et al. (2007), and Ayoola and Makinde (2009) on the sorghum. Decreased in Al and Fe availability in the soil, enhanced soil nutrients (N, P and K), and nutrient uptake by plants might be the key factors affecting the enhancement plant growth performance in acidic soils with rice straw amendment (Jones et al, 2016).

(a)

(b)



(c)

Figure 4.4 : The physical growth performance of F1 hybrid sweet corn 801 variety for three replications with increased in application level at 60 DAP

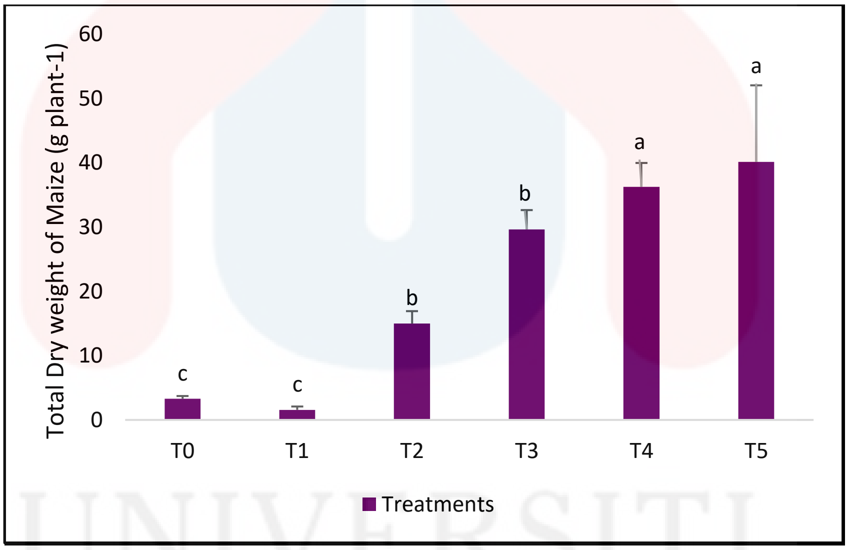
4.5 Effect of Treatments on Dry weight of Maize (*Zea mays*)

Dry weight of hybrid sweet corn 801 (leaf, stem, and root) affected by the application of compost were summarized in Table 4.4.1. At 60 DAP the differences between treatments without rice straw compost (T0 and T1) and treatments with rice straw compost (T2, T3, T4, and T5) were statistically significant with respect to the leaf and stems' dry weight. Pot treated with T4 and T5 produced the largest dry weight among all the rice straw amended and non-amended pot. Compared to T0 and T1, the root's dry weight measured at 60 DAP increased significantly with rice straw amended pots (T2, T3, T4, and T5). The T3, T4, and T5 showed the most pronounced effect (Table 4.4.1). As for the overall dry weight T4 and T5 showed the most pronounced effect among the treatment (Fig. 4.5). The increased in dry matter production of maize plant could be due to the increased in leaf area index (Laekemariam and Gidago, 2013). Leaf area index increased with the amount of rice straw amendment input which indirectly influencing the increased in dry weight of the maize.

Table 4.4.1: Effect of Treatment on Dry weight of hybrid sweet corn (*Zea mays*)

Treatment	Dry weight of plant (g plant^{-1})			
	Leaf	Stem	Root	Total
T0	1.22 ± 0.14 d	0.85 ± 0.27 c	1.21 ± 0.10 b	3.29 ± 0.43 c
T1	0.75 ± 0.28 d	0.66 ± 0.24 c	0.16 ± 0.02 c	1.57 ± 0.52 c
T2	6.68 ± 0.70 c	6.38 ± 1.55 b	1.92 ± 0.35 b	14.98 ± 1.94 b
T3	13.08 ± 0.65 b	11.20 ± 1.75 a	5.37 ± 1.88 a	29.65 ± 2.99 b
T4	18.30 ± 0.91 a	12.46 ± 2.19 a	5.51 ± 2.21 a	36.26 ± 3.71 a
T5	18.66 ± 3.27 a	15.70 ± 6.90 a	5.75 ± 2.18 a	40.12 ± 11.93 a

Different letters within a column indicate significant different between means using Tukey's test at P ≤ 0.05



S.D. Standard deviation. for each treatment and parameter, values with the same alphabets indicate significant different between means at P ≤ 0.05 by using Tukey's test.

Figure 4.5: Effect of Treatment on Dry weight of hybrid sweet corn 801 at 60 DAP

4.6 Plant Nutrient Concentrations and Uptake of Plant Nutrient in leaf, stem and root of F1 hybrid sweet corn 801 variety

The effect of treatments on the plant nutrient concentration in F1 hybrid sweet corn 801 variety was showed in Table 4.5. The concentration of N, P, K, Ca and Mg in plant leaves, stems and roots were considered low in rice straw amended plant at 60 DAP (Table 4.5). The low in plant nutrients concentration could be attributed to the translocation of plant nutrients to the other parts of the plant (Ch'ng *et al*, 2014).

All the rice straw amended plants (T2, T3, T4 and T5) significantly increased in the concentration of N, P, K, Ca, and Mg for each plant parts (leaf, stem and root) compared to nonamended plant (T0 and T1) at 60 DAP (Table 4.5). The T5 showed the most pronounced effect among the treatments for N and K concentration whereas T4 was the most significant in terms of P uptake among the treatments. On the other hand, T1 showed the least nutrient uptake among the treatments. Differences were also observed on the uptake of plant nutrients for each plant parts (leaf, stem and root) at 60 DAP (Table 4.6). The rice straw amended plants (T2, T3, T4 and T5) showed an increased in the N, P, K, Ca, and Mg uptake for each plant parts (leaf, stem and root) compared to nonamended plant (T0 and T1) at 60 DAP (Table 4.6). The increase in the concentration of primary nutrients was due to the microbial mediated mineralization causing an increased in available nutrients for plant uptake (Osman, 2013).

Table 4.5: Nitrogen, Phosphorus, Potassium, Calcium and Magnesium concentrations in leaf, stem and root of F1 hybrid sweet corn 801 variety

Treatment	N	P	K	Ca	Mg
			(%)		
Leaf					
T0	1.35 ± 0.12 c	0.10 ± 0.05 d	0.62 ± 0.04 e	0.08 ± 0.02 d	0.04 ± 0.01 c
T1	0.61 ± 0.17 d	0.26 ± 0.03 d	1.28 ± 0.16 d	0.15 ± 0.01 c	0.01 ± 0.003 d
T2	1.40 ± 0.00 c	0.48 ± 0.04 c	1.87 ± 0.08 c	0.18 ± 0.003 bc	0.07 ± 0.002 b
T3	1.63 ± 0.12 c	0.78 ± 0.13 c	1.86 ± 0.10 c	0.24 ± 0.01 ab	0.09 ± 0.003 b
T4	2.01 ± 0.09 b	2.13 ± 0.41 a	2.96 ± 0.17 b	0.21 ± 0.01 bc	0.12 ± 0.01 a
T5	2.75 ± 0.05 a	1.26 ± 0.22 b	4.17 ± 0.52 a	0.28 ± 0.02 a	0.15 ± 0.01 a
Stem					
T0	0.75 ± 0.05 c	0.15 ± 0.02 d	0.94 ± 0.24 cd	0.10 ± 0.03 c	0.02 ± 0.01 d
T1	0.65 ± 0.12 c	0.08 ± 0.02 e	0.29 ± 0.11 d	0.03 ± 0.01 d	0.01 ± 0.003 d
T2	0.84 ± 0.08 b	0.32 ± 0.07 c	1.45 ± 0.04 c	0.15 ± 0.01 bc	0.09 ± 0.01 c
T3	0.84 ± 0.21 b	0.76 ± 0.12 b	2.77 ± 0.30 b	0.21 ± 0.01 ab	0.10 ± 0.01 bc
T4	1.31 ± 0.05 ab	0.85 ± 0.08 b	5.29 ± 0.08 a	0.21 ± 0.01 ab	0.14 ± 0.01 ab
T5	1.68 ± 0.14 a	1.80 ± 0.23 a	5.70 ± 0.32 a	0.23 ± 0.01 a	0.15 ± 0.01 a
Root					
T0	0.51 ± 0.12 b	0.07 ± 0.02 b	1.22 ± 0.18 cd	0.15 ± 0.01 c	0.04 ± 0.01 c
T1	0.33 ± 0.05 b	0.04 ± 0.01 b	0.62 ± 0.04 d	0.08 ± 0.02 d	0.01 ± 0.003 d
T2	0.65 ± 0.05 b	0.23 ± 0.01 b	1.87 ± 0.08 bc	0.18 ± 0.003 bc	0.06 ± 0.002 c
T3	1.07 ± 0.05 a	0.77 ± 0.03 a	1.86 ± 0.10 bc	0.28 ± 0.02 a	0.10 ± 0.004 b
T4	1.17 ± 0.05 a	0.69 ± 0.14 a	2.21 ± 0.22 b	0.20 ± 0.01 bc	0.12 ± 0.01 b
T5	1.35 ± 0.05 a	0.87 ± 0.05 a	2.96 ± 0.17 a	0.26 ± 0.02 ab	0.15 ± 0.01 a

S.D. Standard deviation. for each treatment and parameter, values with the same alphabets indicate significant different between means at $P \leq 0.05$ by using Tukey's test

Non-applied plant (T0 andT1) were significantly lower compared to amended plants (Table 4.6). The increased in plant nutrients uptake showed that less plant nutrients were lost from the soil through volatilisation and denitrification. The less nutrient lost from the soil could be attributed to the significantly increased soil CEC after the addition of rice straw amendment. High CEC contributed by the rice straw amendments increased the affinity of cations like NH_4^+, K^+, Ca^{2+} and Mg^{2+} in soil. This might reduce the nutrient deficiency and reduce volatilisation and denitrification process. As a result, the concentration of nutrients in the soil increased and became more available for plant uptake. The CEC increased with the increase in application level of rice straw compost for each treatment. Therefore, T5, with the highest CEC due to higher rate of compost application which imposed larger surface area, and had the most abundant nutrient concentration in the leaves (Havlin *et al*, 2005).

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Table 4.6: Effect of different treatments on uptake of N, P, and K in leaf, stem and root of maize plant at 60 DAP

Treatment	Dry weight of plant	N	P	K
	(g plant-1)		(mg plant^{-1})	
Leaf				
T0	1.22 ± 0.14 d	16.59 ± 2.53 d	1.34 ± 0.80 e	7.50 ± 0.34 e
T1	0.75 ± 0.28 d	3.93 ± 1.68 d	1.77 ± 0.60 e	8.87 ± 2.95 e
T2	6.68 ± 0.70 c	93.59 ± 9.87 c	32.76 ± 6.14 d	123.64 ± 7.78 d
T3	13.08 ± 0.65 b	212.69 ± 12.56 bc	101.45 ± 14.46 c	244.11 ± 24.15 c
T4	18.30 ± 0.91 a	365.76 ± 4.25 ab	388.25 ± 71.78 a	544.95 ± 59.52 b
T5	18.66 ± 3.27 a	517.18 ± 97.31 a	219.75 ± 8.01 b	763.89 ± 147.19 a
Stem				
T0	0.85 ± 0.27 c	6.46 ± 2.08 d	1.40 ± 0.57 d	8.51 ± 4.21 e
T1	0.66 ± 0.24 c	3.98 ± 1.58 d	0.60 ± 0.26 d	1.79 ± 0.95 f
T2	6.38 ± 1.55 b	54.84 ± 17.28 c	18.45 ± 2.37 c	91.61 ± 20.01 d
T3	11.20 ± 1.75 a	95.52 ± 29.51 c	88.78 ± 27.33 ab	320.08 ± 86.73 c
T4	12.46 ± 2.19 a	161.46 ± 24.72 ab	109.85 ± 30.08 ab	663.36 ± 127.83 b
T5	15.70 ± 6.90 a	276.86 ± 132.01 a	290.16 ± 128.22 a	936.57 ± 463.45 a
Root				
T0	1.21 ± 0.10 b	5.98 ± 1.04 d	0.86 ± 0.26 c	14.69 ± 2.30 c
T1	0.16 ± 0.02 c	0.54 ± 0.15 d	0.06 ± 0.01 c	0.98 ± 0.05 c
T2	1.92 ± 0.35 b	12.25 ± 1.25 c	4.43 ± 0.97 b	36.43 ± 8.23 b
T3	5.37 ± 1.88 a	58.24 ± 21.73 ab	41.15 ± 14.05 a	99.77 ± 33.99 a
T4	5.51 ± 2.21 a	63.41 ± 24.09 a	43.87 ± 26.03 a	118.23 ± 44.88 a
T5	5.75 ± 2.18 a	79.04 ± 31.48 b	49.61 ± 18.20 a	164.53 ± 55.01 a

S.D. Standard deviation. for each treatment and parameter, values with the same alphabets indicate significant different between means at $P \leq 0.05$ by using Tukey's test

According to Liu *et al* (2015), rice straw compost can affect total nutrient and plant uptake by increasing the soil pH. Reactive groups of rice straw amendments like carboxyl, phenoxyl as well as hydroxyl react with trace elements (Al and Fe) which formed a stable complex. Altering the metals blocking capacity caused by the Al and Fe might be useful in reducing the Al and Fe bioavailability (Zheng *et al*, 2012). This would result in the increase in soil pH and caused the release of more available P in the soil for plant uptake.

The T1 had the lowest plant nutrient uptake in plants and this might due to the drastic immobilisation of chemical fertiliser during plant growth (Pan *et al*, 2018). This immobilisation will reduce the plant uptake and caused the plant to be stunted growth. Inorganic fertilisers like urea was likely to suffer from leaching, denitrification and volatilisation (Park, 2009). Unlike T1, rice straw amendments (T2, T3, T4, and T5) with slow released properties allowed nutrient retention in soil for plant uptake. This might stimulate the alleviation of significantly immobilisation of chemical fertiliser.

According to Zhong (2017), organic amendments had higher effects on most plant microbial indicators compare to chemical fertiliser only. These soil microbes' biomass played an important role in maintaining soil functions as they were the main sources of soil enzyme. They were responsible for element transformation process in the soil. Potthoff, (2001) reported that rice straw amendment had extracellular enzyme activities involved in C, N and P mineralization which in turns releasing more available N and P for plant uptake.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

The study conducted at Universiti Malaysia Kelantan, Jeli Campus, Malaysia in 2018 shows that rice straw compost can enhance the plant growth performance and fertiliser uptake in hybrid sweet corn 801*(Zea mays)* cultivated on a tropical acid soil. Besides, it increases the nutrients availability in the tropical acid soil by reducing NH_3, H_2PO^-, and K^+ loss through volatilisation, leaching and denitrification. The soil pH and the soil EC have a significant increase when rice straw compost is applied. Rice straw compost also increases the total N, available P content, availability P content, availability exchangeable K, Ca, and Mg in tropical acid soil. The results also prove that amending chemical fertiliser with rice straw compost has a larger impact compare to treatment with without compost, particularly the dry matter and the nutrient uptake.

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APPENDICES

Figure A.1: Collected soil samples for analysis

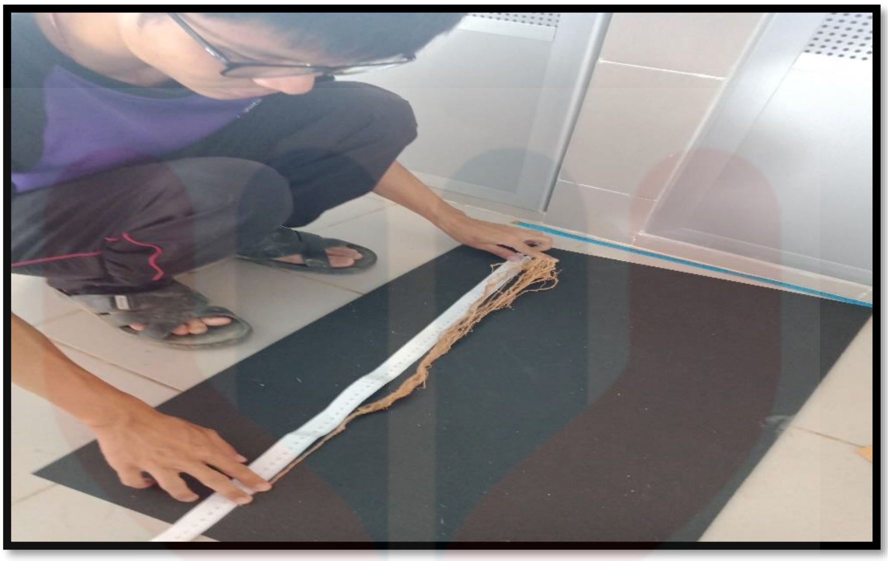
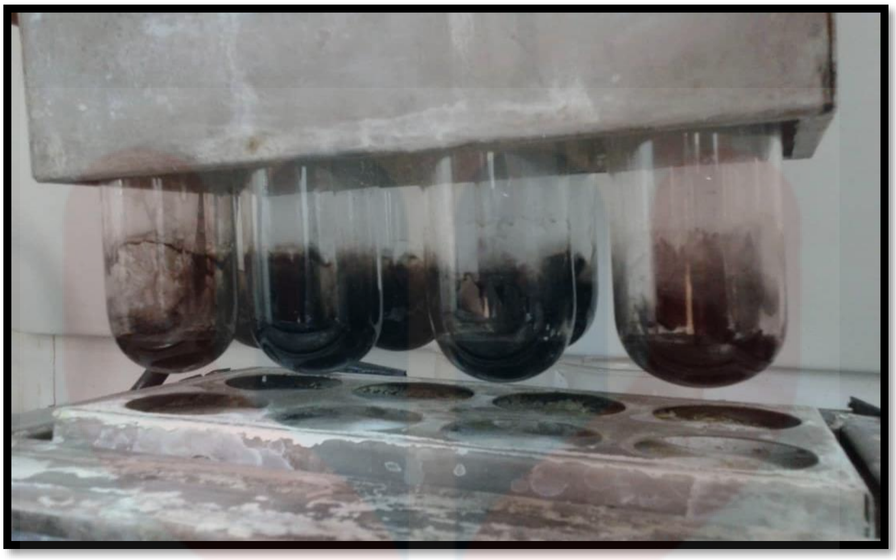


Figure A.2: Measuring of root length

Figure A.3: Result of Root length



(a)

(b)

Figure A.4 : Samples for Kjeldahl method before heating

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