PRODUCTION OF FERTILIZER USING FOOD WASTE FROM CAFETERIA , UMKKJ

by

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DECLARATION

I declare that this thesis entitled ‘Production of Fertilizer Using Food Waste from Cafeteria, UMKKJ’ is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :_________________________________

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Production of Fertilizer Using Food Waste from Cafeteria, UMKKJ

ABSTRACT

Cafeteria UMKKJ produced food wastes everyday and this caused a problem in waste management system. It used up a large amount of land, water and fertilizer only to be buried in a landfill. The food in landfill decomposes and emits methane gas which contribute to global warming. The food wastes such as vegetable waste, eggshell and chicken bone can be used to produce organic fertilizers that useful for farmers. Eggshell and chicken bone were cleaned, sterilized and turned into powder form by using blender whereas vegetable waste was mixed with sawdust in a bin for composting. Vegetable compost had the highest K content compared to chicken bone and eggshell at 425.87%, 39.16% and 17.49%. Eggshell had the highest P content followed by vegetable compost and chicken bone at 3.36%, 0.77% and 0.70% whereas chicken bone had the highest N content followed by vegetable compost and eggshell at 2.02%, 0.49% and 0.34%. These composts' C:N ratio had between 5:1 and 30:1 which were 9.21, 14.45 and 18.60 for eggshell, vegetable compost and chicken bone. Different composition of fertilizers were applied to the key lime plants and the growth performance was observed and recorded. By applying the organic fertilizer, the plants grow better in terms of height, leaves, fruit and flower number, root growth and chlorophyll content. Based on the observation, soil with vegetable compost and eggshell in ratio of 0.5:0.5 (T2), vegetable compost and eggshell in ratio of 1:1 (T1) and vegetable compost, chicken bone and eggshell in ratio of 1:1:1 (T6) had better plant growth compared to control and other compost treatments (T0,T3,T4,T5 and T7).

Penghasilan Baja Dengan penggunaan Sisa Makanan Dari Kafetaria UMKKJ

ABSTRAK

Kafetaria UMKKJ menghasilkan sisa makanan setiap hari dan menyebabkan masalah dalam sistem pengurusan sisa makanan. Sisa makanan menggunakan tanah, air dan baja sahaja yang berjumlah besar untuk dikebumikan dalam tapak pelupusan sampah. Sisa makanan dalam tapak pelupusan sampah terurai dan melepaskan gas metana yang menyumbang kepada pemanasan global. Contohnya, sisa sayur, kulit telur dan tulang ayam boleh digunakan untuk menghasilkan baja organik yang berfaedah kepada petani. Kulit telur dan tulang ayam dibersihkan, disterilkan dan ditukar kepada serbuk dengan menggunakan pengisar manakala sisa sayur dicampur dengan habuk papan dalam tong untuk pengkomposan. Sisa sayur mempunyai kandungan potasium yang paling tinggi berbanding dengan tulang ayam dan kulit telur pada 425.87%, 39.16% dan 17.49%. Kulit telur mempunyai kandungan fosforus yang tertinggi, diikuti oleh sisa sayur dan tulang ayam pada 3.36%, 0.77% dan 0.70% manakala tulang ayam mempunyai kandungan nitrogen diikuti oleh sisa sayur dan kulit telur pada 2.02%,0.49% dan 0.34%. Nisbah C:N dalam kulit telur, sisa sayur dan tulang ayam adalah antara 5 dan 30, iaitu 9.21, 14.45 dan 18.60. Komposisi baja yang berlainan digunakan untuk pokok limau nipis dan prestasi pertumbuhan diperhatikan dan direkodkan. Dengan penggunaan baja organik, pokok bertumbuh lebih baik dari segi ketinggian, kuantiti daun, buah dan bunga, pertumbuhan akar dan kandungan klorofil. Berdasarkan pemerhatian, tanah dengan kompos sayuran dan kulit telur dalam nisbah 0.5:0.5 (T2), kompos sayuran dan kulit telur dalam nisbah 1:1 (T1) dan kompos sayuran, tulang ayam dan kulit telur dalam nisbah 1:1:1 (T6) bertumbuh lebih baik berbanding dengan rawatan kawalan dan rawatan kompos lain (T0, T3, T4, T5 and T7).

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LIST OF ABBREVIATION AND SYMBOLS

Al	Aluminium
ATP	Adenosine Triphosphate
C	Carbon
Ca	Calcium
Cu	Copper
FAO	Food and Agriculture Organization Of United Nation
Fe	Iron
HCl	Hydrochloric acid
H_2SO_4	Sulphuric acid
K	Potassium
K_2O	Potassium oxide
MBM	Meat and bone meal
Mg	Magnesium
MSW	Municipal solid waste
N	Nitrogen
NaOH	Sodium hydroxide
OM	Organic matter
P	Phosphorus
P_2O_5	Phosphorus pentoxide
pH	Potential of hydrogen
SmF	Submerged fermentation
SPAD	Soil-Plant Analyses Development
SSF	Solid state fermentation

T	Treatment
Zn	Zinc

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Food waste is generated everyday due to living nature of human beings through industrial, agricultural and domestic activities. There are three different types of food waste sources which are food losses, unavoidable food waste and avoidable food waste (Thi *et al.*, 2015). There is approximately one-third of food produced for human consumption is wasted or lost which reached the amount of 1.3 billion tonnes per year (FAO, 2015). According to Alias (2010), municipal solid waste (MSW) produced in Malaysia was 7.34 million tons in 2005, and it is predicted to increase to 10.9 million tons in 2020. At Korea, food waste is about 60% of the MSW, hence the estimated amount of food waste produced in 2005 was 4.404 million tons and was estimated to increase to 6.54 million tons in 2020 (Lee *et al.*, 2007).

In addition, Malaysia is trying to solve the problems during management of MSW and finding the most environmental-friendly solutions which can be easily accepted by the public. In Malaysia, there is no separation for food waste management system and food waste is treated as part of MSW. Since food waste is the largest contributor to MSW, solutions for MSW should be taken (Kathrivale *et* *al.*, 2003). Hence, the food waste disposal is categorized under MSW disposal, which under the Malaysia Solid Waste and Public Cleansing Management Act 2007(Act 672) (Ngapan *et al.*, 2012). The most common method for food waste disposal is sending them to landfill. This is because it is a cost-effective, simple application and widely accepted solution for managing food waste. As many landfills have reached their maximum capacity, food waste management through landfill has become more difficult in Malaysia (Moh and Manaf, 2014). The large amount of food waste produced is the main factor to issues that related to landfills such as toxic leachate, foul odor, vermin infestation and the emission of greenhouse gases (Lee *et al.,* 2007).

In order to reduce food waste, composting can be applied as part of food waste management. Composting is biological decomposition of organic matter into a stable, dark humus product in aerobic condition. Compost consists of the by-products of this decomposition, the biomass of both dead and living microorganisms, and the undegradeable parts of the raw material make up the end product. The organisms that responsible for composting need standard nutritional and environmental conditions such as temperature and pH to survive and function. Besides, they also require suitable amounts of macro- and micro-nutrients, oxygen and water (Robert, Gwendolyn & Donald, 2000). By composting, the food waste can be turned into fertilizer which is giving benefits to the plantation and at the same time reducing the amount of food waste to landfill.

Therefore, this research aims to produce organic fertilizer derived from food waste collected from cafeterias at Kampus Jeli, Universiti Malaysia Kelantan. Later, the organic fertilizer was tested on the key lime plants to observe the effectiveness of different fertilizer compositions on the growth performance of the plants.

1.2 Problem Statement

Increased generation of food waste is a global problem (Mason, Boyle, Fyfe, Smith & Cordell, 2011). According to Pleissner and Carol (2013), there is around 1.3 billion tonnes of food waste generated by a population of 30 million every year in the world. This includes all types of food such as vegetables and fruits, eggs and seafood. Based on the Food and Agriculture Organization's (FAO) research, it stated that food is lost and wasted from the production of agricultural activity to the hands of consumers. Food waste is a waste that can decompose and recycle in dominant composition of municipal solid waste generated in Malaysia (The Sun Daily, 2014). Currently, there are some types of technologies applied in the waste management system of Malaysia such as recycling, composting, sending to the inert landfill or sanitary landfills and other disposal sites. However, the main waste disposal method in Malaysia is disposing all types of wastes into landfills without any pre-treatment. The landfills that operated in this country are in bad conditions such as poor leachate treatment, gas ventilation and lining systems (Ismail and Manaf, 2013). It is estimated that the emission of greenhouse gases will be increased up to 50 % by 2020 if the country still depends on landfill as waste disposal methods. There are many environmental problems associated with landfills such as groundwater contamination, air and soil pollution. By converting the food waste into organic fertilizer via anaerobic fermentation, the emission of greenhouse gases and the amount of food waste send to landfills can be reduced. Besides, this fertilizer can be used to improve plant growth.

1.3 Objectives

The objectives of this research are:

(i) to produce organic fertilizer by using food waste collected from UMKKJ cafeteria.

(ii) to characterize the nutrient contents from the soil samples and fertilizers that derived from vegetable compost, eggshells and chicken bones.

(iii) to determine the effectiveness of different composition of prepared organic fertilizers on the growth of key lime plant.

1.4 Scope of study

This study focuses on the production of organic fertilizers by using food wastes such as eggshells, chicken bones and vegetables generated from UMKKJ's cafeteria. The effectiveness of the fertilizer was determined by observing the growth performance of key lime plant.

During composting, pH and temperature were measured to record the changes during the process. After preparing fertilizers, different combination of fertilizer was applied to 8 different key lime plant pots as tabulated in Table 1.1.

Table 1.1: List of fertilizer composition used in different pots of key lime plant.

Pot Number	Composition of vegetable compost, chicken bone powder and eggshell
T0	Soil only with no fertilizer
T1	Soil + Vegetable compost
T2	Soil +Vegetable compost: Chicken bones in ratio of 1: 1
T3	Soil +Vegetable compost: Chicken bones in ratio of 1: 0.5
T4	Soil +Vegetable compost: Eggshells in ratio of 1: 1
T5	Soil +Vegetable compost: Eggshells in ratio of 1: 0.5
T6	Soil +Vegetable compost: Chicken bones : Eggshells in ratio of 1: 1: 1
T7	Soil +Vegetable compost: Chicken bones: Eggshells in ratio of 1: 0.5: 0.5

*T1, T2, T3, T4, T5, T6, T7 were applied with 2 tablespoons of vegetable compost per pot to sustain the growth of key lime plants except for T0.

The growth performance of key lime plant in different pots was observed for about 5 weeks. A positive (apply vegetable compost only to the plant) and negative treatment (no fertilizer application) were set as the control experiment. The soil pH, NPK percentage, height, flower number and leaf number of the plant were determined during the observation process.

1.5 Significance of study

There are too much food wastes generated from the stalls of UMKKJ cafeteria every day. This includes vegetables, fruits, chicken bones, fish bone and eggshell. The workers are just disposing the food waste into bins without any treatments. Hence, the food waste that used in this research was collected from the cafeteria, UMKKJ. The production of organic fertilizers using food waste such as eggshells, vegetables and chicken bones can be made at home and anytime. The fees for the raw materials are almost zero. By using organic fertilizers, the amount of food waste generated from cafeteria can be reduced. Hence, the environmental problems related to landfill such as greenhouse gases emission can be reduced.

Although there are studies on different organic fertilizer, they are produced and tested separately in different plants. There was no previous study about the combination of food waste such as eggshells, vegetables and chicken bones to produce organic fertilizers. Besides, in this study the effectiveness of the organic fertilizer produced was determined by observing their effects on the growth of key lime plants.

1.6 Study Area

The food wastes were collected from cafeteria at Universiti Malaysia Kelantan, Kampus Jeli.

CHAPTER 2

LITERATURE REVIEW

2.1 Process in production of organic fertilizers

There is some process that transform the food waste into organic fertilizers such as fermentation, solid state fermentation, submerged fermentation and composting. During fermentation process, the natural substrate has been utilized as the source of carbon and occurred in absence of free liquid. In solid state fermentation, it is the process that happen in absence of free liquid by employing a natural or inert substrate as its' solid support (Quarterly, 2008). Moreover, the submerged fermentation is the process that used free flowing liquid substrates and it is suitable for bacteria which require high moisture content (Subramaniyam & Vimala, 2012). Composting is a process of controlled biological maturity in the presence of oxygen, where the organic matter is decomposed to materials that posed shorter molecular chains (Sequi, 1996). All these processes were explained in the next sub-sections.

2.1.1 Fermentation

Fermentation is a technique used to convert the complex substances into simple compounds biologically by different types of microorganisms such as fungi and bacteria. Additional compounds such as alcohol and carbon dioxide are released from this metabolic breakdown (Balakrishnan and Pandey, 1996; Machado *et al*., 2004; Robinson *et al.,*2001). The classification of fermentation based on the types of substrates used which is Solid State Fermentation (SSF) and Submerged Fermentation (SmF) (Subramaniyam & Vimala, 2012).

2.1.2 Solid State Fermentation (SSF)

Solid State Fermentation is a type of fermentation process where microorganisms grow on solid materials such as paper pulp and bagasse in the absence of free liquid. The objectives of solid state fermentation process are to bring the fungi or bacteria that was cultivated in contact with the inert substrate and to achieve the highest concentration of nutrients for fermentation (Quarterly, 2008). Temperature and its heat transfer process are the factor of influencing the growth of fungi and production of secondary metabolites. A large amount of heat is produced during solid state fermentation which is proportional to metabolic activities of microorganisms. The range of temperature that suit for fungal growth is from 20 to 50 ℃. The microbial activities and aeration during fermentation are directly related to heat transfer process. An increase in temperature will affect the germination, the formation of metabolite and sporulation of fungi (Bhargav et al., 2008). The nutrient-rich waste materials are recyclable as substrate is one of the benefits of using these substrate. Therefore, the utilization of the substrates is very slow and steady, and this ensure that it can be used for longer times (Subramaniyam & Vimala, 2012).

2.1.3 Submerged Fermentation (SmF)

Unlike SSF, submerged fermentation uses free flowing liquid substrates such as broths and molasses. It also differs from SSF in terms of the rate of substrate utilization. The substrate needs to be replaced because it is used up rapidly. This type of fermentation is the best suit for microorganisms that need high moisture content. The advantage of this process is that the product purification that is easy to handle. The secondary metabolites in liquid form can be extracted during submerged fermentation (Subramaniyam & Vimala, 2012).

2.1.4 Composting

Composting is separated into two phases which are degradation and maturation. First phase is degradation of the most easily degrading organisms by aerobic microorganisms to produce carbon dioxide and energy. It happens in the presence of oxygen. The next phase of the composting process is maturation of the materials in order to produce humus and aromatic compounds. Temperature and pH are crucial in production of compost but the optimum temperature for composting will be changed during the process. There are three phases that can be differentiated which are mesophilic (moderate temperature), thermophilic (high temperature) and cooling and maturation phases. The optimum pH range for compost microorganisms is between 5.5 and 8.5. As the pH is reduced, the microbial activity will be limited if it is an anaerobic condition. Composting brings many advantages such as improving soil tilt condition and structure, supporting living soil organisms and helps to dissolve mineral forms of nutrients (Oreopoulou & Russ, 2007).

2.2 Fertilizers from food waste

Organic fertilizers are the by-products of daily life from using organic material such as manure, agricultural waste and food waste (Singh., 2012). There are some advantages of using organic fertilizers such as enhancing soil biological activity, increasing the organic matter content of the soil, releasing the nutrients slowly and hence reducing the nitrogen leaching loss and phosphorus fixation (Chen, 2008).

2.2.1 Food waste

Food waste is defined as the waste that produced during processing of industry, distribution and final consumption (Buchner et al., 2012). Food wastes are produced in homes, institution and camps and these food waste should be remove in order to provide a clean environment. Through composting, these wastes can be reduced and hence produce compost which helps in better crop productivity (Okareh, Oyewole & Taiwo, 2014). Food waste has high energy content and it seems to achieve waste stabilization and energy production (Sun-Kee & Hang-Sik, 2004).

Nitrogen elements in organic materials cannot be absorbed directly by the plant, so it needs to mineralize to nitrate or exchangeable ammonium with the help of microorganisms in soils. Microbes utilize the carbon for cell building and nitrogen for the synthesis of protein. The optimum C:N ratio is on the range of 20:1. The organisms will absorb nitrogen and transform the excess organic nitrogen into ammonium if the C:N ratio is less than 20:1. The microbial activities increase and microbes will uptake the plant-available sources of nitrogen of the C:N ratio is more than 20:1. This will bring the deficiency symptoms to the plants when a high C:N ratio compound is added to the soil (Lin, 2008).

About 95 % of the dry eggshell is calcium carbonate weighing 5.5 g. But, the average eggshell has about 0.3 % phosphorus and 0.3 % magnesium and traces of sodium, potassium, zinc, manganese, iron and copper (Butcher & Miles, 2012). The ground poultry bone residue contained 13 to 15 % protein, 16 to 20 % fat, and 8 to 11 % ash (Lawrence *et al.,*1982). The bone residue contained 6400 mg calcium and 2800 mg phosphorus per-100 g. Therefore, it would be feasible to the industry to investigate the use of such by-products for making broth for human consumption (Young *et al.,* 1983).

Temperature and pH are the factors that influence in the degradation of food wastes into organic fertilizers. Carbohydrate, cellulose and protein that found in food waste need different optimal temperature, pH and retention times for composting. The optimum temperature for composting of food wastes is ranging from 28 to 65 ℃ whereas the pH suitable for composting is around 6.3 to 7.1 (Okareh *et al.*, 2014).

According to Ylivainio *et al*. (2007) and Garcia and Rosentrater (2006), meat and bone meal (MBM) is the by-product of the rendering industry. It consists of 10 % Calcium (Ca), 8 % Nitrogen (N), 5 % Phosphorus (P) and 1 % Potassium (K), which are the source of nutrients for plant production.

According to Madhavi Gaonkar and Chakraborty (2016), eggshells are discarded as wastes from various sources. After collecting, purifying and turning into powder by blender, eggshell powder was used as the fertilizer in the production of tomato plant. By using the eggshells as fertilizer, it can improve nutrient holding capacity, improve micronutrient transfer to plant's circulation system and as a source of phosphate increasing the cohesive forces of the very fine soil and carbon by stimulating the population of micro flora (Harsha Sharadchandra, 2015).

According to Dumitrescu *et al*. (2009), they concluded that the recycling biomass waste by composting vegetables waste with sawdust and sewage sludge into biofertilizer compost which has a high nutritive value for plants and good amendments of soil characteristics. During composting, the microbial communities developed had greater access to aliphatic structures, thus increasing the intensity of aromatic structures.

2.2.2 Application of eggshell as fertilizer

According to Madhavi and Chakraborty (2016), collected and purified eggshell and turn it to powder by using blender. The eggshell powder was used as a fertilizer in a tomato plant and used as calcium supplement for females. In addition, they extracted calcium from various eggshells and characterized them using Fourier Transform Infrared Spectroscopy (FTIR). The FTIR results showed that eggshell which is about 11 % of the total weight of the whole egg contains about 91 % of calcium carbonate. In this research, they utilized eggshells as the fertilizer in plant which is very beneficial for plants that suffered from blossom-end-root diseases. Other than that, it also can increase the nutritional intake of plants.

2.2.3 Meat bone meal (MBM) as fertilizer on yield and quality of sugar beet and carrot

Jukka *et al.* (2015) compared the yield and quality of sugar beet and carrot that applied with the MBM and mineral fertilizers. They found that MBM fertilization on the sugar beet provided lower yields when compared with the mineral fertilizer at only 11.4 % and 19.6 % whereas on the carrot, it only provided 14 % lower total root yield than mineral fertilization. This indicated that adding extra fertilizer during combined or separating fertilizer applications had no effect on the yield and quality of root. This was because the nitrogen supply from MBM is not enough for achieving the same or higher yields as with mineral fertilizer. Hence, MBM can be utilized to soils with low phosphorus status. They concluded that MBM is a reasonably competitive alternative to mineral fertilizers, and as a recycled fertilizer it is an option for organic production.

2.2.4 Production of fertilizer using food wastes of vegetables and fruits

According to Tan (2015), the objectives of the study are to produce organic fertilizers by using food wastes such as vegetables and fruits, to determine the fungi involved during fermentation for production of fertilizer and to evaluate the effectiveness of produced organic fertilizers on water spinach's growth. In the study, the brown sugar was added in the sample in order to test the effectiveness of brown sugar in the fermentation. The fungi were isolated from solid and liquid samples of fertilizer during the fermentation in order to test the types of fungi that present in the fertilizer. From the findings, she found that the liquid organic fertilizers that produced from food wastes showed higher plant height and percentage of dry matter when compared to the plants that grown in commercial fertilizer.

2.3 Benefits of organic fertilizers from food waste

The application of organic fertilizer as a source of nutrients to add into the soil for improving the plant growth. It contributes to high level of organic matters and diverse microorganisms. It offers more significant advantages such as increasing organic matter in soil, improving drainage in clay soils and thus controlling soil erosion. Hence, environmental impacts are reduced such as waterlogging, nutrient loss, eutrophication of waterways and surface crusting. All of this problem solved by improving water retention in soil, soil properties and associated plant growth. It also can replace the application of chemical fertilizers. This is very crucial for the production of a good quality agricultural product for food industry (Oreopoulou & Russ, 2007).

To be sustainable, organic agriculture must also be profitable (Reganold *et al*., 2011). The factors that determine the profitability of organic agriculture include labor costs, crop productivities, potential for reduced income during the organic transition period and potential cost savings from the reduced use of purchased inputs (Zentner *et al*., 2011). The chemical fertilizers and herbicides can be replaced and the compost by using the waste materials can be used for providing nutrients to plants and soil (Oreopoulou & Russ, 2007).

2.4 Key lime *(Citrus aurantifolia)* as growing plant

The scientific name of key lime is *Citrus aurantifolia* and it is a native of the subtropical areas of south-eastern Asia. It is one of the member of *Rutace*ae family which including lemons,limes and pomelo. Key lime is a type of warm-growing fruit that needs warm to hot conditions over 5 to 6 months to produce high productivity and quality fruits. The optimum growing temperature range is between 21℃ and 31 ℃ whereas the optimal soil temperature for germination of seeds is from 24 ℃ to 32 ℃. Key limes are shallow rooting, cold-sensitive and thorny plants. But, they grow on well-drained soils, protection against cold wind and good air circulation. Therefore, topping and pruning was adopted for providing sunlight and maximising air circulation. The desirable soil pH is between 6 and 7. In order to control the weed growth, black plastic mulch is used to manage weeds within row. Organic manure is applied before transplanting because it will improve soil structure, retain soil moisture content and supply organic matter to the soil. Regular application of nitrogen is needed especially the growing season (Ullio, 2003).

CHAPTER 3

MATERIALS AND METHODOLOGY

3.1 Materials Preparation

3.1.1 Collection of Food Waste Materials (eggshells, vegetables and bones)

The food waste such as vegetables, eggshells and chicken bones were collected from cafeteria of UMK, Kampus Jeli. The food waste was separated into different bags for further use.

3.1.2 Preparation of Food Waste Materials

3.1.2.1 Process of converting chicken bones into powder form

The collected chicken bone was stored in the freezer until it is enough. After taking from the freezer, wait for the chicken bone to thaw completely. The chicken bones were cleaned and sterilized for use. To sterilize them, the chicken bones were spread on an aluminium foil and then placed under the broiler at 200 ℃ for 10 to 15 minutes. To ensure the bones will be easily stripped clean of any fat or meat tissue still stuck to them, they were gently simmer at 100 ℃ with just enough water to cover them for 5 to 8 hours. The bones were dried by spreading them on a plate and placing them in a well-ventilated area to dry. Normally, the bones need to wait to dry completely. This makes it easy to turn into a powder. Once the bones are brittle and dry, they were crushed into smaller pieces. A mortar and pestle were used in this step. Every time, only small batches were crushed to create an evenly fine powder. After that, blender was used to make the bones into fine powder. Once the bones ground up, the bone meal for plants was ready for use.

3.1.2.2 Process of converting eggshells into organic fertilizer

After collection, eggshells were cleaned with tap water. Then, 12 pieces of eggshells were boiled with 6 cups of distilled water for 10 minutes. After the eggshells are drained out, they were spread out on the aluminium foil and dried overnight. The next day, the eggshells were dried again in oven at 200 ℃ for about 10 minutes. Then, they were crushed into smaller pieces by using mortar and pestle. They were blended into granular form by using the blender (Gaonkar & Chakraborty, 2016).

3.1.2.3 Process of converting vegetables into organic fertilizer

Organic fertilizers was made by mixing vegetable wastes and sawdust in a composting bin. (Dumitrescu *et al*., 2008).

A composting bin with a few holes (Figure 3.1) was prepared to perform this experiment (Neugebauer & Sołowiej, 2017). The compost heap was built up of two layers of materials. The first layer was placed with dry plant materials such as sawdust, thick and long stalks and straws of maize. Before placing into the bin, the materials were broken into shorter lengths (10 to 15cm) by crushing and chopping them. Then, the crushed and dry materials were spread evenly over the bottom of the composting bin (about 15 to 25 cm thick).

In order to ensure they are moist, water was evenly by hand or sprinkling with watering. Next, a 20 to 25cm thick layer of moist plant materials such as rotten vegetables were spread on the first layer. If they were chopped up, the leafy branches from woody plants were used in this layer. Water was not allowed to sprinkle or scatter on this layer. The layers were added until it is full and the second layer was thicker than first layer. To ensure good ventilation and test the soil regularly, a testing stick such as bamboo grass or bamboo was placed vertically in the compost heap. The stick can be taken out.

Then, a covering layer such as leaves of banana with plastic was used to cover the compost with only the stick coming out of the top. The compost was left untouched until it became dark brown or black. The storing period was like 3 months. Water was sprinkled over the layers to ensure the materials are moist if the compost is turned over. A mature compost has good smell, present in dark brown or black humus and is almost half of the original height. After the preparation process, the mature compost was used immediately and it was needed to be covered by soil immediately to prevent the damage of the sun and wind (Fallis, 2013).

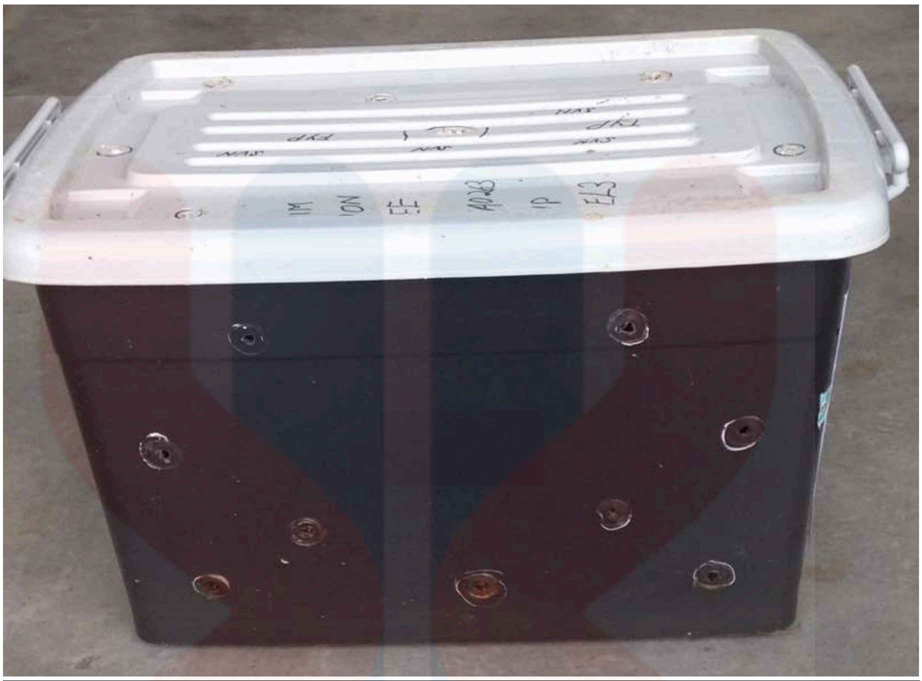

Figure 3.1: Composting bin with a few holes that was used in this experiment.

3.2 Phytoxicity test

According to Zucconi et al. (1981), a phytoxicity test was carried out based on germination bioassay. 10 g of ground and dried compost was weighed and 100 mL of distilled water was added into 250 mL beaker, and shaked for 24 hours. Then, the samples were centrifuged for 20 minutes at 10,000 rpm and the supernatants were filtered through Whatman No.42 filter paper. The extract was diluted five times and another one with distilled water act as control. The pH of these extract was then determined. 10 green beans were put in petri dishes lined with Whatman No.42 filter paper. A 5 mL of extract was pipetted on each petri dish and one petri dish with 5 mL distilled water served as control. Parafilm was used to seal each petri dish to allow penetration of air and prevent water loss. Next, all petri dishes were placed inside a cupboard for seed germination. Each replicate was made up of ten seeds.

After 72 hours, the seed germination, root and shoot lengths were counted and measured for all the extracts and the control. The germination index was counted as follows: Germination index = (G (%) × RRG (%)) × 100 (3.1)

where G (%) = (number of seeds germinated in a sample/ number of seeds germinated in the control) × 100

RRG (%) = (mean root length in a sample/ mean root length in the control) × 100

3.3 Soil Analysis

Before the pot experiment was carried out, the soil was analyzed for soil pH, soil extractable K, soil available P and soil total N.

3.3.1 Soil pH

Potentiometer method was used to determine the soil pH. In this method, a ratio of 1:2.5 (soil and distilled water suspension) was used to measure soil pH by using the digital pH meter (Peech, 1965). A 12.5 mL of distilled water together with 5 g of air-dried soil was added in beaker at a ratio of 1:2.5 and this procedure was repeated for 3 times. The sample was shaken at 180 rpm using a shaker for 15 minutes. After that, the sample was left overnight for 24 hours before using a digital pH meter for pH determination.

3.3.2 Soil Total Organic Matter (OM) and Total Carbon(C) Determination

According to Tan (2003), combustion was adopted to determine the total OM and total C in this research. The air-dried samples were placed in an oven at 60 ℃ for 24 hours. The samples were cool down using desiccator. In the beginning, the initial weight of the crucible with lid was recorded. Then, the weight of the crucible with lid was weighed with the addition of 5 g of the soil sample. Next, the soil samples were ashed in the muffle furnace at 300 ℃ for an hour and the temperature was increased to 550 ℃ for another 8 hours. Then, samples were allowed to cool before inspection. The weight of the sample in the porcelain after ashing was calculated. According to Tan (2003), the total OM and C were calculated by using the following calculations:

$$\text{Total OM } (\%) = \frac{D}{I} \times 100 \quad (3.2)$$

where D (g) = Initial weight of soil sample − final weight of soil sample

I (g) = initial weight of soil sample

$$\text{Total C} = X \times 0.58 \quad (3.3)$$

3.3.3 Soil Extractable Al, K, Ca, Mg, Cu, Zn and Fe Determination

Soil extractable Al, K, Ca, Mg, Cu, Zn and Fe were extracted using the Mehlich No.1 Double Acid Method (Mehlich, 1953). The double acid was prepared by mixing 4.1 mL HCL and 1.35mL H_2SO_4 in 1 L volumetric flask and diluting to 1 L. A 10 g of soil sample was weighed and placed into a 50 mL beaker. After that, a

40 mL of the extraction reagent was added and the solution was shaken for about 10 minutes on a reciprocal shaker. Then, the supernatant was filtered into another beaker using Whatman Filter Paper No. 2, and the extract was collected. Next, the extract was filtered through syringe filter into a 50 mL volumetric flask and dilute to 50 mL with extracting solution. An Atomic Absorption Spectrophotometer (AAS) was calibrated and the extract was aspirated into AAS and the reading was recorded. The soil exchangeable cations were calculated using Equation 3.4 (Mehlich, 1953).

$$\text{Soil exchangeable cation (ppm)} = \text{AAS reading (ppm)} \times \frac{V}{W} \qquad (3.4)$$

where V (mL) = Volume of extractant

W (g) = Weight of soil sample

3.3.4 Soil Available P Determination

Mehlich No. 1 Double Acid Method was used to extract P in soil (Mehlich, 1953). A 4.1 mL of concentrated HCl and 1.35 mL of concentrated H_2SO_4 was pipetted into a 1000 mL volumetric flask and the volume were made up to 1L volume. A 5 g of sample was weighed and placed into a 50 mL beaker. After that, a 20 mL of the extraction reagent was added. Next, the solution was shaken for 10 minutes on reciprocal shaker. Then, 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 & Riley, 1962). Reagent A (6 g molybdate + 0.145g antimonyl in 74 ml H_2SO_4) was prepared and diluted up to 1 L with distilled water in 1 L volumetric flask. Reagent B (250 ml Reagent A and 1.32 g ascorbic acid) must be freshly prepared. Then, 8 ml Reagent B was pipetted into 50 ml volumetric flask and 2 ml of soil extract was pipetted, followed by a few drops of distilled water and swirled it. After developing blue colour, the solution was pipetted into cuvette and analysed by UV-vis spectrophotometer at 882 nm wavelength.

$$\text{Soil Available P (ppm)} = \text{UV-vis reading} \times \frac{20}{5} \times \frac{V}{S} \times \text{dilution factor (if any)} \qquad (3.5)$$

where V (mL) = Volume of volumetric flask

S (mL) = Volume of sample added

3.3.5 Soil Total N

A 0.5 g of soil was weighed (sieved to pass 0.5 mm) into 50 mL Kjeldhal digestion tubes. The 5 mL of concentrated sulphuric acid was added into digestion tube. A tablet of Kjeldhal catalyst was added. The samples were shaken allowed to equilibrate for 30 minutes. Next, the samples were heated in a digestion block at 400 ℃ for 4 hours until samples become colourless. The samples were allowed to cool down. On cooling, 30 mL distilled water was added. The sand fraction if any should be left in the Kjeldhal flask, was made up to 100 mL when the solution is cool. A 10 mL of the sample was pipetted into distillation apparatus. A 10 mL of 40% NaOH was added (e.g. 40% NaOH = (400g NaOH /1 L distilled water)× 100). The distillate was distilled and collected in 10 mL of 2% boric acid-indicator solution. The colour was changed from purple to green during distillation. A 2% boric acid was prepared by weighing 23 g of pure boric acid (H_3BO_3) and adding distilled water up to 1 L in a 1 L volumetric flask. About 250 mL of water was added. It was heated and swirled until the boric acid dissolves and then it was allowed to cool. A 20 mL of mixed indicator (0.099 g bromocresol green + 0.066 g methyl red in 100 mL of ethanol) was added. A 0.01 M H_2SO_4 (0.54ml of concentrated H_2SO_4 was diluted up to 1 L in a volumetric flask) was titrated against until the colour changes from green to purple. Percentage Nitrogen in soil was calculated by using Equation 3.6:

$$N (\%) = [(V-B) \times M \times R \times 14.01/W_t \times 1000] \times 100 \quad (3.6)$$

Where: V = Volume of 0.01 M H_2SO_4 titrated for the sample (mL)

B = Digested blank titration volume (mL)

M = Molarity of H_2SO_4 solution

14.01 = Atomic weight of N

R = Ratio between total volume of the digest and the digest volume used for distillation

W_t = Weight of air-dry soil (g)

3.4 Compost Characterization

The compost was analyzed for pH, total N, P and K. The procedure for analyzing total N were similar to the previous procedures described in the previous sections.

3.4.1 Total P and K Determination

Total P and K in the compost were determined by using the Single Dry Ashing Method (Jones *et al.*, 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 one hour to 520 °C and was ashing for another 5 hours. The sample was cool in a dessicator. After that, the sample was added with few drops of distilled water followed by 2 mL of concentrated HCl. The sample was then evaporated to dryness in the fume chamber using hot plate. Next, 10 mL of 20% HNO_3 was added to the sample and was allowed to heat for further one hour. The sample was then be filtered to pass Whatman Filter Paper No.2 into 100 mL volumetric flask and was made up to the volume. For the K determination, the sample was aspirated into AAS and the absorbance reading was taken. The molybdenum blue method (Murphy & Riley, 1962) was used to determine the total P in the compost. The blue colour was analyzed using UV spectrophotometer at 882 nm wavelength.

3.5 Pot experiment and Treatments

A pot experiment was conducted in the Nursery of UMKKJ. A total of 8 pots were filled with soil. The test crop used in this pot experiment was key lime plant. As the cultivation of key lime plants was done in this pot experiment, each of the pots were supplied with organic fertilizers to ensure the optimum growth of the plants. The fertilizers that were being applied are vegetable compost, powdered chicken bones and eggshells. However, the composition of vegetable compost, powdered chicken bones and eggshells were varied as shown in Table 1.1. These fertilizers were applied once within 2 weeks.

This experiment was conducted over a period of five weeks between October and November 2018 at nursery of UMKKJ. The key lime plants were bought from Nursery of Ranrau Panjang. During growing season, key lime plants were watered in the early morning and evening. The following effects were measured and recorded once a week: soil pH, height, flower number, leaves number and fruit number. Graphs were plotted based on the readings taken.

3.6 Post-treatment Soil Analysis

The soil samples were collected after harvesting stage. The soil samples were collected, air-dried, crushed and sieved using 2-mm sieve. After that, the soil samples were analyzed for pH, soil total N, soil available P and soil extractable K, Al, Fe, Cu, Fe, Zn and Mg using the same procedure described previously.

3.6.1 Chlorophyll content

The chlorophyll content was measured by using the SPAD 502 Plus chlorophyll meter. Three section of plants' leaves (top, middle and bottom) were measured and average reading was taken. These steps were repeated for the left one.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Selected Physical Properties of Compost

4.1.1 Temperature of compost (vegetable waste and sawdust)

There are three typical composting phases were observed (Figure 4.1) during the composting process. Throughout the composting period, the ambient temperature was between 29℃ to 33 ℃. On 27th May 2018 (first day), the temperature of the compost was at the mesophilic stage. At the mesophilic stage of the composting process, mesophilic bacteria consuming was available and this leads to production of substansial amount of metabolic heat energy that caused the temperature to increase to the thermophilic stage (Day and Shaw, 2000). High temperature of the compost was unfavourable for those mesophilic bacteria and thus the mesophilic microorganisms also became less competitive. Then, the temperature increased to the thermophilic stage (45 ℃) and further increased to 53 ℃. The thermophilic stage was maintained between 45 ℃ to 55℃ from the evening of 4th June to 12nd June 2018. The thermophilic microbes (*Bacillus sp.)* available and responsible for the decomposition of protein and other carbohydrate compounds. Some more stable material such as lignin was oxidized in the thermophilic stage (Baffi *et al*., 2006). Fungi are the main microorganisms present in the compost when cellulose, hemicellulose and lignin are available whereas bacteria and actinomycetes change the degradable substrates such as proteins and carbohydrate compounds (Ayed *et al*., 2007).

Next, the temperature was decreased gradually to 44 °C. A second mesophilic stage as the food sources of thermophilic organisms started to decrease on 24th June 2018. A turning over was done on 25th June and after that the temperature was increased to thermophilic stage (52 °C). The turning and mixing of the compost were to improve the aeration for aerobic microbes. The compost's temperature dropped and it did not restore by the turning and mixing at the end of thermophilic phase (Trautmann and Krasny 1997). The temperature was maintained in the range of 39 °C to 42 °C from 26th to 30th July 2018. At the end of composting process, the average temperature of the finished compost product was 33 °C which was equal to the ambient temperature of 32 °C. The *Coprinus sp*. mushrooms that found growing on the compost were the fruiting bodies of fungi, each of which was connected to an extensive network of hyphae. When the fungi start to dominate the compost, it indicated that the bacteria gradually died off. This suggested that the compost was mature but not all compounds get fully broken down into simple ions. The microorganisms in the composting were able to join some of the chemical breakdown products together into long chains called polymers. These resist further decomposition and become part of the complex organic mixture called humus and the formation of humic compounds (Graves and Hattemer 2000). The matured compost product was brownish-black in colour, soft, coarse and had a good smell compared to the vegetable wastes (Figure 4.2).

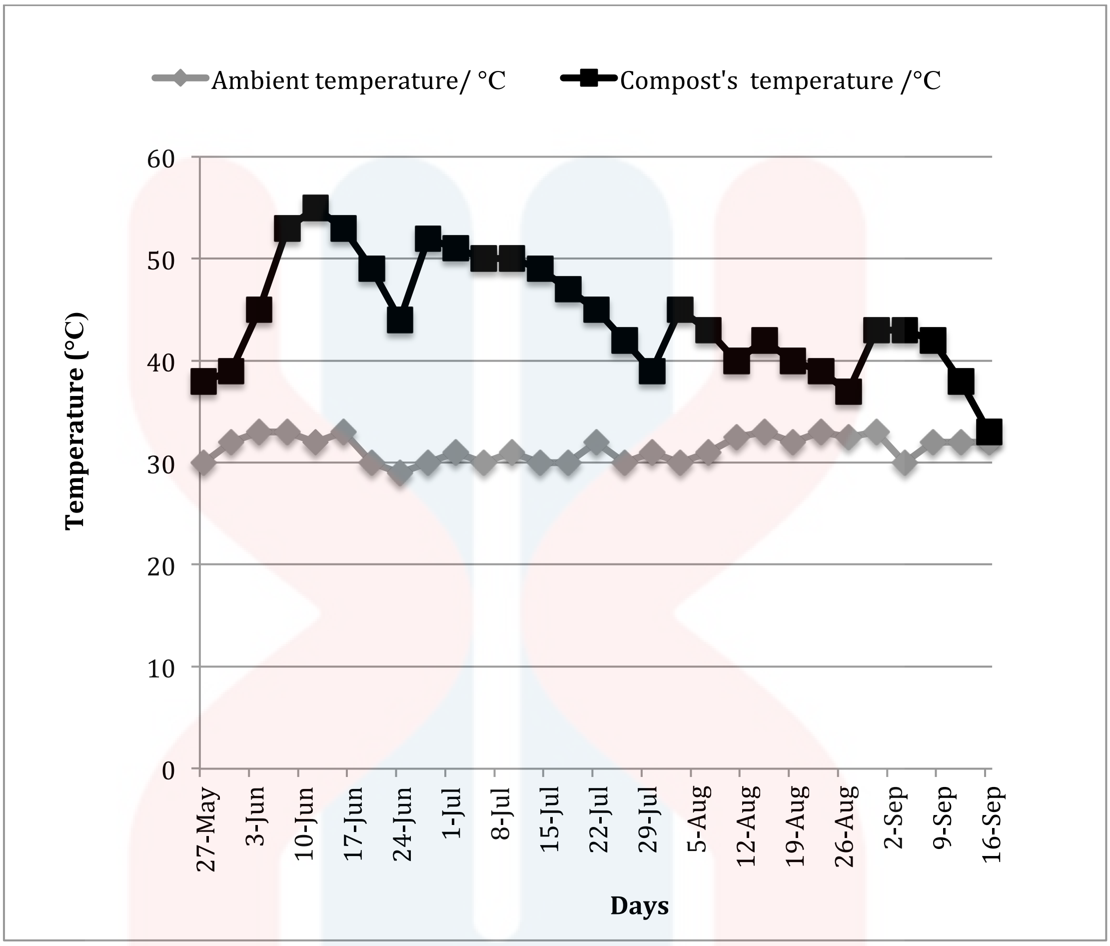

Figure 4.1: Temperature of compost (vegetable waste and sawdust)

Figure 4.2: Colour and texture of compost (vegetable wastes and sawdust)

4.1.2 pH of compost

Figure 4.3 shows the pH of the compost. On the first day, the pH value of the compost was 4.8 which was acidic. This was because reduced pH and high concentrations of organic acids happen during the initial phase of composting process (Beck-Friis *et al.,* 2003). Then, the pH value was increased to 6.4 and dropped to 5.9 on 6th July 2018. After that, the pH increased gradually to 6.9 from 19th August and maintained until the finish compost was produced. This due to the acids were decomposed, the pH of the compost increased during successful composting (Beck-Friis *et al.,* 2003).

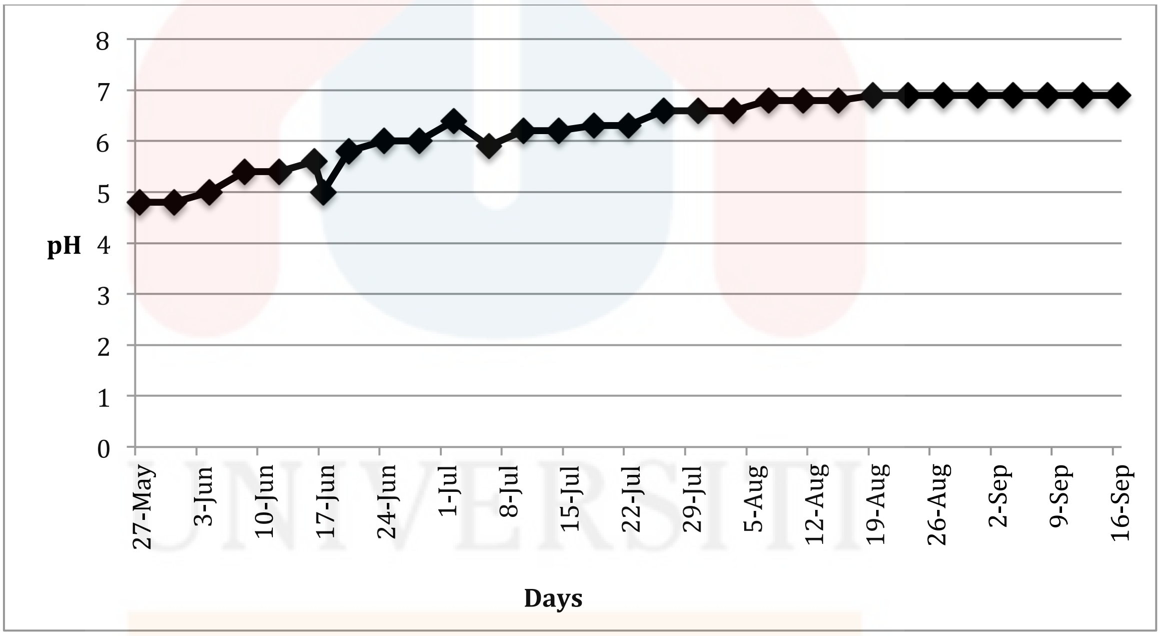

Figure 4.3: pH of the compost (vegetable waste and sawdust)

4.2 Selected Physico-Chemical Properties of Soil Samples

Table 4.1 showed the selected physico-chemical properties of the soil sample for all pots prior to experiment. The soil had a low pH of 5.75. The soil also contained relative high concentration of Fe due to the low soil pH.

Table 4.1: Selected physico-chemical properties of soil sample

Property	Value Obtained
pH (water)	5.75
Total Organic Matter (%)	4
Total Carbon (%)	2.32
Total N (%)	0.056
Available P (ppm)	0.98
C/N Ratio	41.43
C/P Ratio	2.37
Exchangeable K (ppm)	100.36
Exchangeable Ca (ppm)	102.40
Exchangeable Mg (ppm)	22.54
Exchangeable Fe (ppm)	87.04
Exchangeable Cu (ppm)	1.33
Exchangeable Zn (ppm)	1.9

4.3 Selected Chemical Properties of Compost

Compost not only contributes macronutrients like N, P and K which are immediately plant available, but also micronutrients that present in trace amount. Due to the types of wastes used in the compost, different micronutrients may be added, including Cu, Fe and Zn. These nutrient elements are also important for plant growth because usually inorganic fertilizers contain only macronutrient (Gardiner & Miller, 2008). The selected chemical properties of different composts are shown in Table 4.2. Chicken bone contained the highest carbon and organic matter, followed by vegetable compost and eggshell. Vegetable compost had the highest K content, followed by the chicken bone and eggshell. Besides, eggshell had the highest P content compared to vegetable compost and chicken bone. On the other hand, the chicken bone had the highest N content, followed by vegetable compost and eggshell. The low C:N ratio of compost suggest that net mineralization of the compost. The high C:P ratio of the compost suggested the possibility of P immobilization (Table 4.2).

Table 4.2: Selected chemical properties of compost (vegetable waste), eggshell and chicken bone

Property	Value Obtained		
	Compost (vegetable waste and sawdust)	Eggshell	Chicken Bones
Total Organic Matter (%)	31.4	5.4	64.8
Total Carbon (%)	18.21	3.132	37.58
Total N (%)	0.49	0.34	2.02
Total P (%)	0.77	3.36	0.70
Total K (%)	425.87	17.49	39.16
C/N Ratio	14.45	9.21	18.60
C/P Ratio	37.16	0.93	53.69

4.4 Summary of phytoxicity test (seed germination) and pH for compost

4.4.1 Determination of germination index of vegetable wastes compost

Table 4.3 shows a germination index of vegetable waste compost on green beans. Vegetable compost ($\times10000$) has the highest germination index which is 122.4 %, followed by vegetable compost ($\times100$), vegetable compost (original), control, vegetable compost ($\times1000$) and vegetable compost ($\times10$). According to Selim *et al* (2012), the green beans germination indices in the compost were greater than 60 % regardless of dilution factor ($\times10$, $\times100$, $\times1000$ and $\times1000$) (Table 4.3). This suggested that the phytotoxicity of the compost pile has been lost. Loss of phytotoxicity is a measure of the compost's maturity level. Based on the germination indices values, compost produced from vegetable wastes and sawdust was mature and ready to use as fertilizer.

Table 4.3: Germination index for compost and distilled water on green beans

Compost	Mean root length (cm)	Mean shoot length (cm)	Mean seed germination (%)	Relative seed germination (%)	Relative root growth (%)	Germination index (%)
Vegetables (original)	2.49	2.45	100	100	105.1	105.1
Vegetables (×10)	1.90	2.95	100	100	80.2	80.2
Vegetables (×100)	2.50	2.92	100	100	105.5	105.5
Vegetables (×1000)	2.06	3.15	100	100	86.9	86.9
Vegetables (×10000)	2.90	2.47	100	100	122.4	122.4
Control (distilled water)	2.37	3.14	100	100	100	100

4.4.2 Determination of pH for compost (vegetable wastes and sawdust) and distilled water (control) in germination bioassay

The pH of compost, dilution factors and distilled water were tested and recorded. The pH value of compost decreased when it was diluted (Table 4.4).

Table 4.4: pH for compost and distilled water

	control	original	10	100	1000	10000
pH	5.84	6.65	6.6	5.89	5.07	4.99

4.5 Treatment Analysis along Monitoring Week

The pH of soil during cultivation of key lime plants was shown in Table A-1 to A-3 (Refer to Appendix A).

4.5.1 Soil pH during cultivation of key lime plants

The average soil pH in key lime plants during the monitoring week (T1- T7) was shown in Figure 4.4. The soil treated with mixture of vegetable compost, eggshells and chicken bones (T2-T6) showed significant increase in soil pH compared to the soil with no treatment (T0) and soil with vegetable compost (T1). Due to the rapid proton exchange between soil and compost supplied, the soil pH increases and it contributed the limiting effects to the soils (Ch'ng *et al*., 2015; Xu *et al*., 2014). The soil pH increment was due to the reduction of exchangeable Al in the low pH of soil. Besides, the levels of exchangeable bases like Ca, K and Mg increased in compost treatments (T2-T7) and this led to an increment in pH value. Hence, there were many nutrients present in less acidic soils (Alley and Vanlauwe, 2009). Generally, the soil pH in the soil with no treatment (T0) decreased to more acidic soil.

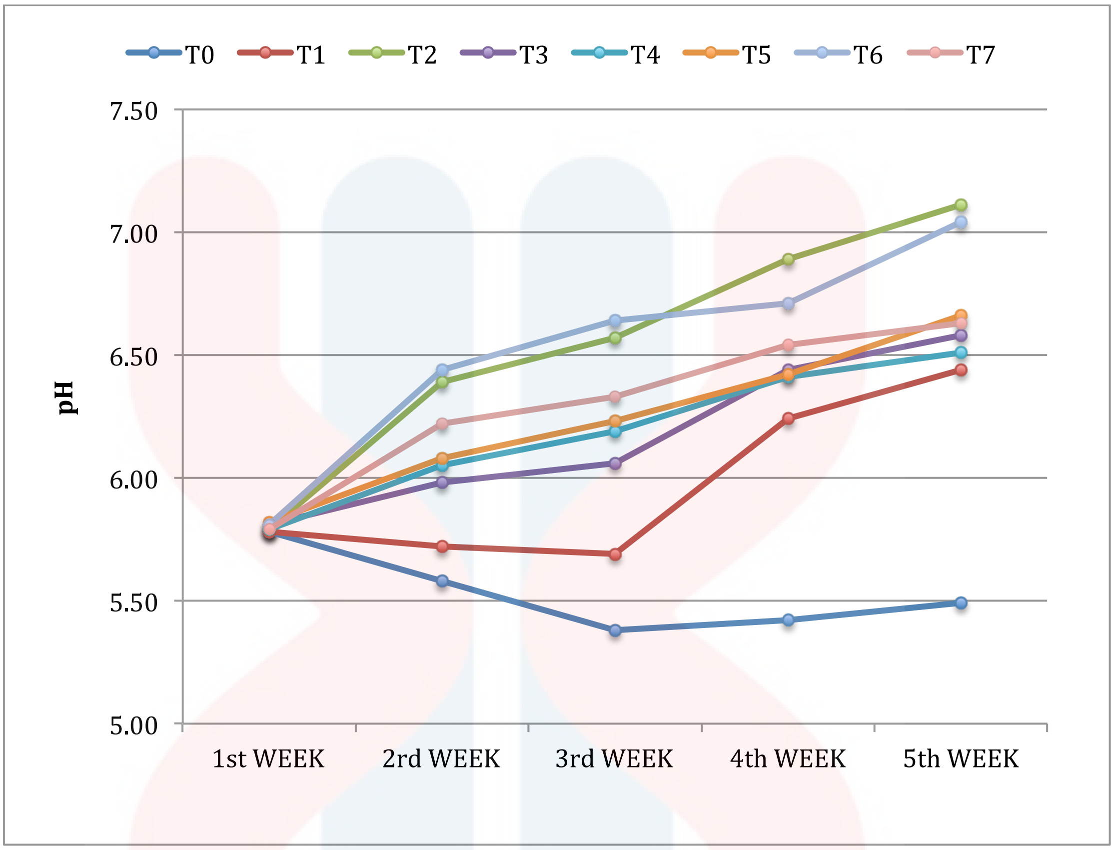

Figure 4.4: Average soil pH during cultivation of key lime plants

4.6 The Effect of Treatment on Selected Physico-Chemical Properties of Plants and Soil after Pot Experiment

4.6.1 Physical properties of plants

4.6.1.1 Height of key lime plants

The percentage of increase in height of key lime plants (T0-T7) are shown in Figure 4.5. Generally, all the treatments had an increment of plants' height. But, plant with vegetable compost only (T1) had a significant increase in plants' height compared to soil with no treatment (T0) and other compost treatments (T2-T7). Plant height extension will give an effect on overall development of canopy (Reddy *et* *al.*,1997). Under N, P and K deficiency condition, the plant became shorter due to the effects upon the cell elongation and cell division (Roggatz et al.,1999).

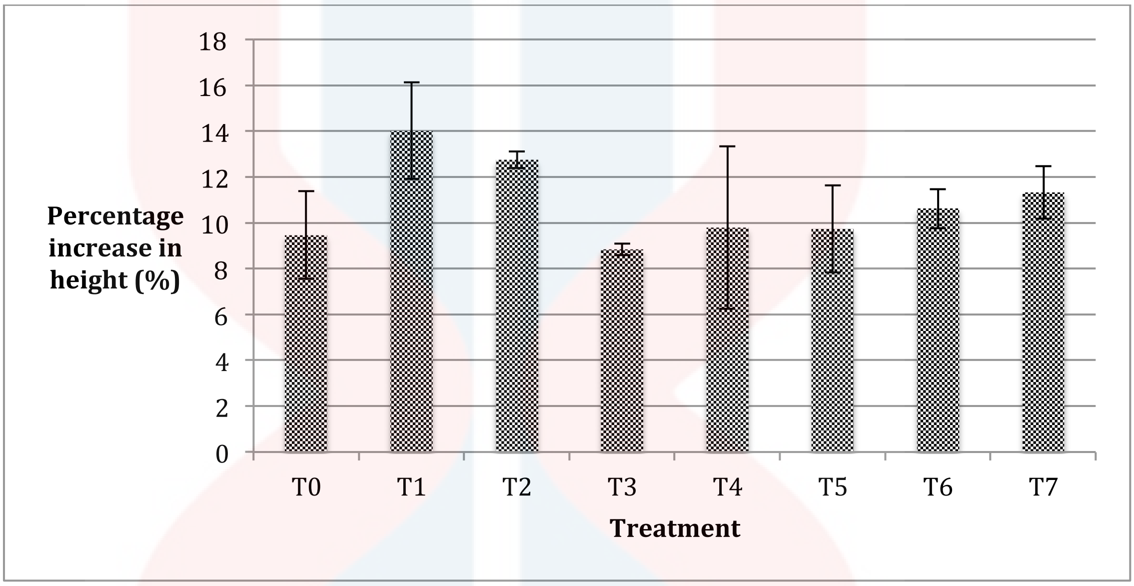

Figure 4.5: Percentage of increase in plants' height

4.6.1.2 Leaves number of key lime plants

Figure 4.6 shows the percentage of increase in leaf numbers. Based on the figure, T0 which is control experiment pot had no increase in leaf number compared to other pots (T1-T7). The leaves number of other pots had increased during the monitoring weeks. The soil with vegetable compost and chicken bone (T3) had the highest increase in leaves number but it also shows a high standard deviation as 7.19. The soil with vegetable compost, chicken bone and eggshell (T6) is the second higher increment which is the value of 11.9 in leaf numbers but lower standard deviation with 6.17. Soil with vegetable compost and eggshell (T4) had the higher increase in leaf numbers compared to soil with vegetable compost and chicken bone

(T2). This was due to the high P content that present in eggshell. Since it promotes the stability of plants in unfavourable condition, green pigments in leaves depend upon the concentration of P (Bojovic & Stojanovic, 2006). The other compost treatments had less increase in number of leaves because their compost contain less P content. Under condition of P deficiency, leaf expansion is more retarded and slower and stunted growth. The symptoms usually happen in older leaves first (Barry, 1996).

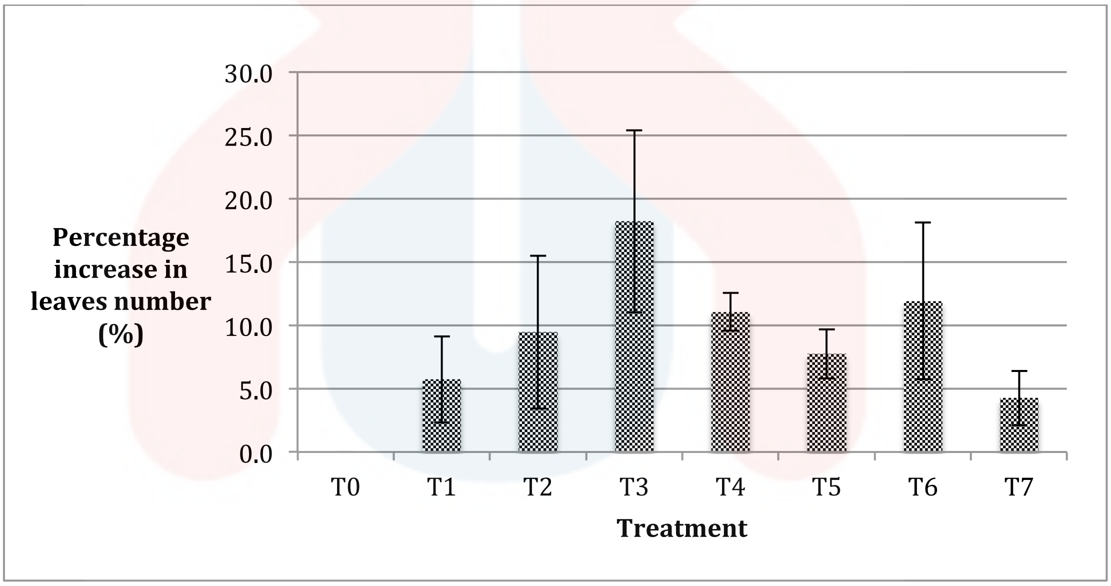

Figure 4.6: Percentage of increase in leaf numbers

4.6.1.3 Fruit and Flower numbers of key lime plants

Figure 4.7 and 4.8 show the number of fruits and flowers in different pots respectively. Based on the Figure 4.7, it shows that T1, T2, T6 and T7 had the significant increase in fruit numbers and this was influenced by K content in vegetable compost, chicken bone and eggshell. Soil with vegetable compost and chicken bone (T2) has the higher increase in fruit numbers compared to soil without treatment (T0). K is an important nutrient element for plant growth and fruit production. It also plays crucial role in stimulating the photosynthesis and their transport of photosynthates to flowers and fruits (Mengel and Kirkby,1987). Under K deficiency condition, less ATP is formed and it will affect the transport system. This led to reduction in photosynthesis rate. On the other hand, K plays role in activation of the enzyme responsible for starch synthesis (starch synthetase). Under sufficient K concentration, starch able to move from production sites to storage organs. Based on the Figure 4.8, it shows that T1, T2, T6 and T7 had the significant increase in flower numbers and this was influenced by P, N and K content in vegetable compost, chicken bone and eggshell. Soil with vegetable compost, chicken bone and eggshell (T6) has the higher increase in flower numbers compared to soil without treatment (T0). This is due to phosphorus that highest present in eggshell and it is most associated with flower growth and production, N and K, along with the secondary nutrients and micronutrients, are all vital.

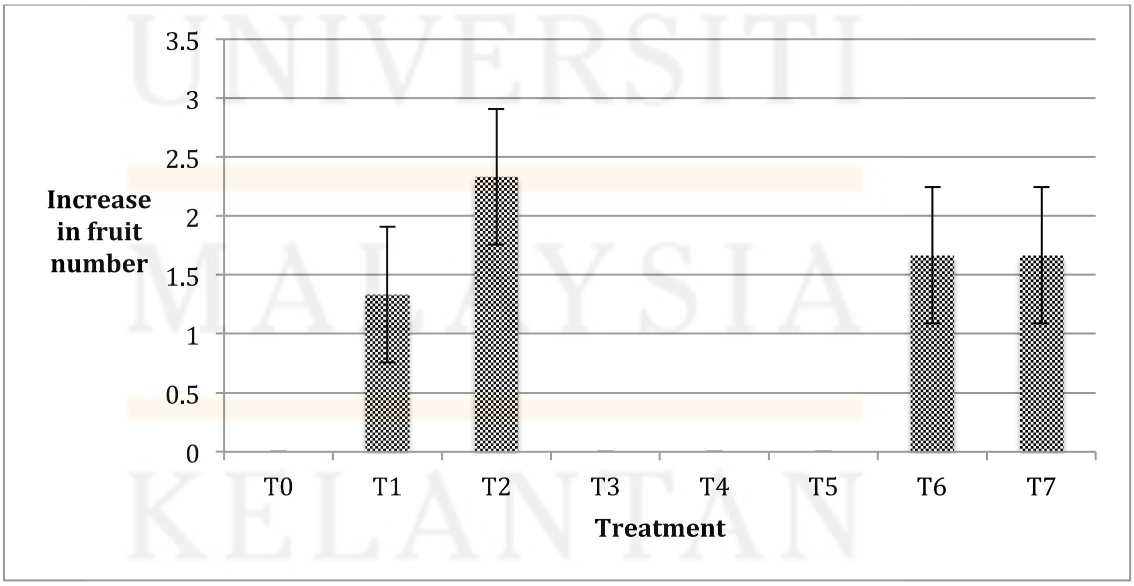

Figure 4.7: Average increase in fruit numbers

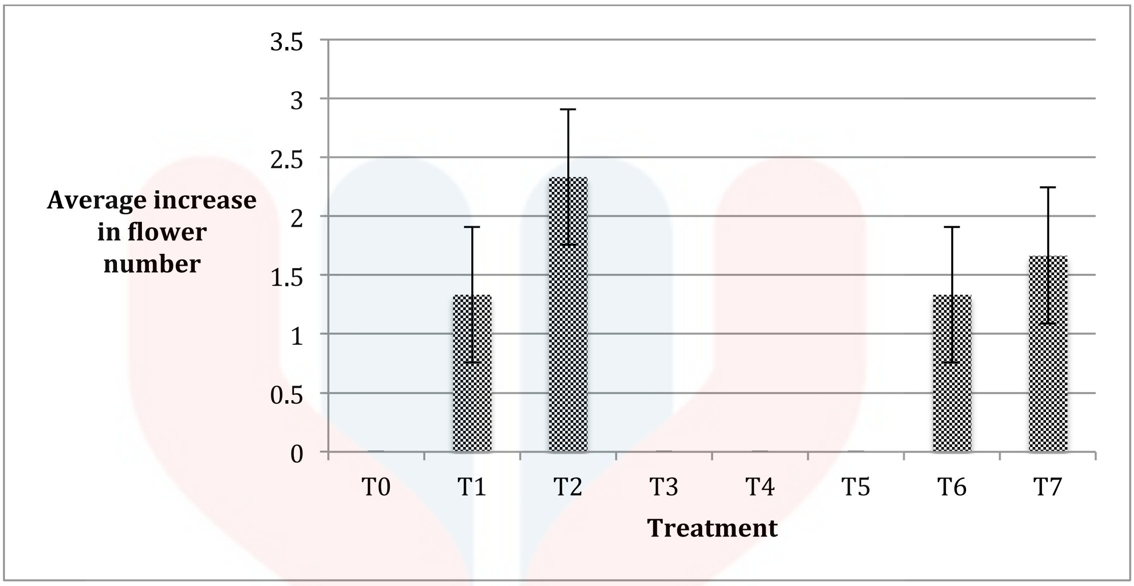

Figure 4.8: Average increase in flower numbers

4.6.1.4 Chlorophyll content in leaves of key lime plants

Figure 4.9 shows the chlorophyll value in all pots. The chlorophyll value in leaves of plant only (T0) was the lowest compared to other treatments. Soil with vegetable compost and chicken bones (T2 and T3) had a high chlorophyll value compared to other compost treatments. Soil with vegetable, chicken bone and eggshell (T6) has a higher chlorophyll content than the other pots without chicken bones. This was due to chicken bones rich in N content which is responsible for formation of active photosynthetic pigments by increasing the quantity of stromal and thylakoid proteins in leaves (Cooke *et al*., 2005; Filho *et al*., 2011), as well as by promoting the chloroplasts formation during leaf growth (Li *et al*., 2012). N may produce negative effects if in excess amount such as decreased the life span of the leaves (Van Lelyveld *et al*., 1990). Chlorophyll synthesis is dependent on the mineral nutrition (Daughtry *et al*., 2000). This is due to the availability of N which important in chlorophyll biosynthesis and cell division. Generally, the chlorophyll content of all compost treatments is higher than soil without treatment (T0). This is because chicken bones have the higher value of N which is 2.02, followed by vegetable compost and eggshells with 0.49 and 0.34 respectively.

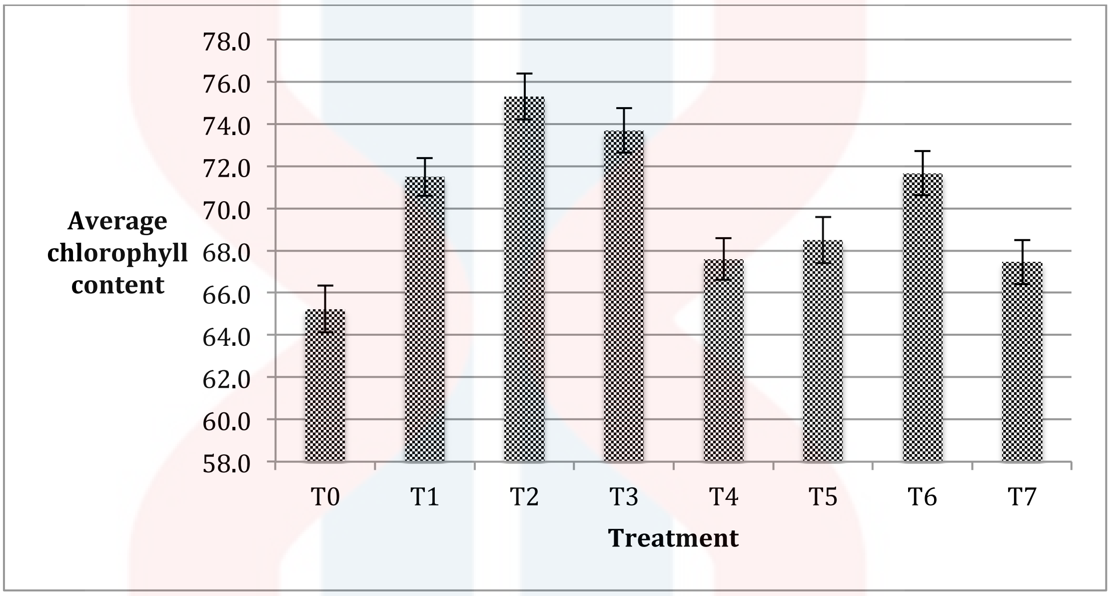

Figure 4.9: Average chlorophyll content in leaves of key lime plants

4.6.2 Effects of Treatment on Selected Chemical Properties of Soil after Pot Experiment

4.6.2.1 Selected Chemical Properties of Soil after Pot Experiment

Table 4.5 shows the average of total OM, total C and N, available P, exchangeable K, Al, Ca, Mg, Fe, Cu and Zn. Therefore, the total OM, C and N and exchangeable K, Ca and Mg in compost treatments (T1-T7) had showed significant increase compared to the soil only (T0). This was due to the high concentration of OM, C, N, K, Ca and Mg in vegetable compost, eggshell and chicken bone. According to Erica *et al.* (2011), the greatest performance was obtained with a C:N ratio between 5 and 30 stimulated the synthesis of laccase and inhibited growth of mycelia. Generally, increment in C:N ratio led to a more stable pH and better methenogenic activity due to improved digestion medium's buffering effect. This is due to the optimum C:N ratio for the organic fertilizers. According to Tanimu *et al.* (2014), there was the highest enzymatic activities of 85 % at C:N ratio is 30:1.

Therefore, the available P and exchangeable Al, Fe, Zn and Cu decreased in the all compost treatments (T1-T7) compared to soil without treatment (T0). Soil with vegetable compost and eggshell (T4 and T5) and soil with vegetable compost, chicken bone and eggshell (T6 and T7) showed there was a significant decrease in concentration of P, Al, Fe, Zn and Cu compared to soil without treatment (T0). This was due to the chelation of Al and other cation in the soil (Yong *et al*., 2001). The compost produces humic substances and organic acid that have functional groups with negatively charge surface after the decomposition process of compost. There was an increase of sorption between Al and Fe instead of P and a decrease in the Al ion exchangeability due to high affinity of functional groups (Ch'ng *et al.,* 2015).

Figure 4.10 to 4.12 show the average effects of Total N, Available P and Exchangeable K of key lime plants after pot experiment. Based on the Figure 4.10, soil with vegetable compost, chicken bone and eggshell (T6) has the highest N content compared to soil with vegetable compost and eggshell (T5). This is due to high N content present in the chicken bone. From Figure 4.11, it shows that soil with vegetable compost and eggshell (T4 and T5) have a higher value of P content compared to soil without fertilizer (T0). This is due to the higher P content in eggshell and vegetable compost. Based on the Figure 4.12, the soil with vegetable compost and chicken bone (T2&T3) has higher K content compared to soil without fertilizer (T0). This is due to the high K content in vegetable compost and chicken bone.

Table 4.5: Selected Average Chemical Properties of Soil after Pot Experiment

Property	Value Obtained							
	T0	T1	T2	T3	T4	T5	T6	T7
Total Organic Matter (%)	4.1	4.6	7.3	4.8	5.2	4.2	5.6	4.7
Total C (%)	2.36	2.67	4.22	2.78	3.02	2.42	3.25	2.74
Total N (%)	0.06	0.08	0.19	0.10	0.21	0.13	0.25	0.16
Available P (ppm)	55	113.3	174	113.3	86.7	62.2	66.7	48.9
Exchangeable K (ppm)	95.4	249.12	312.23	257.96	144.98	103.16	219.19	150.69
Exchangeable Al (ppm)	290.1	208	135.88	220.01	-2.83	-3.59	-3.53	-4.89
Exchangeable Ca (ppm)	143.4	363.51	2953.9	1104.1	4772	4473.3	5283.6	4898.7
Exchangeable Mg (ppm)	26.17	32.76	90.07	54.56	89.89	83.94	101.15	94.03
Exchangeable Fe (ppm)	87.04	51.46	12.33	49.73	0.64	0.45	0.37	0.42
Exchangeable Cu (ppm)	1.33	0.89	0.53	0.71	0.31	0.25	0.28	0.35
Exchangeable Zn (ppm)	1.90	2.22	7.65	2.47	0.17	0.16	0.11	0.28

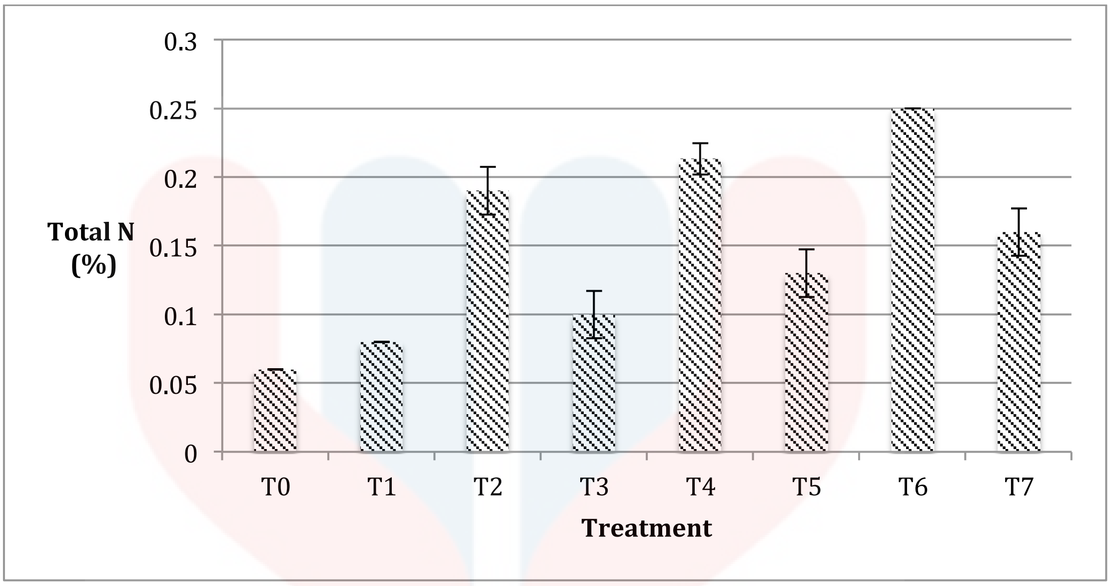

Figure 4.10: Average effect of treatments on Total N of key lime plants after pot experiment.

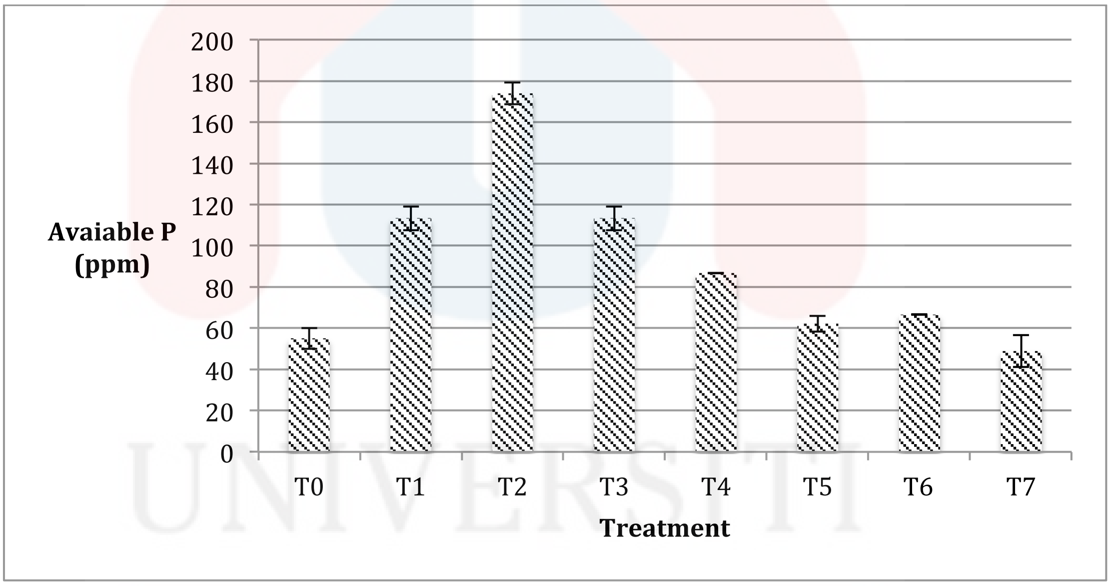

Figure 4.11: Average effect of treatments on Available P of key lime plants after pot experiment.

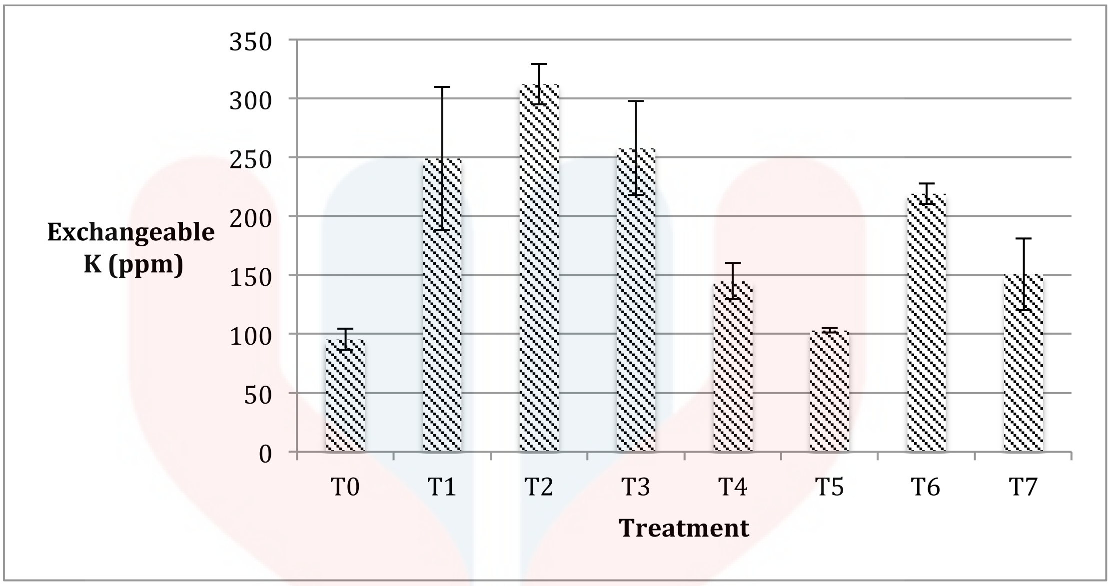

Figure 4.12: Average effect of treatments on Exchangeable K of key lime plants after pot experiment.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Compost derived from vegetable waste, eggshell and chicken bone can be used to improve total N, available P and exchangeable K of key lime plants. Vegetable compost had the highest K content compared to chicken bone and eggshell with 425.87 %, 39.16 % and 17.49 % respectively. Eggshell has the highest P content followed by vegetable compost and chicken bone with 3.36 %, 0.77 % and 0.70 % respectively whereas chicken bone had the highest N content followed by vegetable compost and eggshell at 2.02 %, 0.49 % and 0.34 %. The C:N ratio of these compost had between 5 and 30 which were 9.21, 14.45 and 18.60 for eggshell, vegetable compost and chicken bone. This is proven as treatment with compost significantly increased the soil pH and total OM, C, N, P, Ca and K whereas reduced exchangeable Al, Fe, Cu and Zn in the soil. On the other hand, the differences between pot without treatment (T0) and other pot with treatments (T1-T7) showed that application of composts was supplying the nutrients on the key lime plants. Based on the observation, soil with vegetable compost and eggshell in ratio of 0.5:0.5 (T2), vegetable compost and eggshell in ratio of 1:1 (T1) and vegetable compost, chicken bone and eggshell in ratio of 1:1:1 (T6) had better plant growth compared to control (T0) and other compost treatments (T0, T3, T4, T5 and T7). As conclusion, organic amendment application able to reduce the soil exchangeable Al, Fe, Cu and Zn, increase the soil available P, C, N, Ca and K and pH, re-construct the soil's chemical properties and hence decreasing the quantity of phosphate fertilizer applied to the soil.

5.2 Recommendation

As for recommendation, this study can be further evaluated in the field for at least 3 cycles to confirm the findings. In addition, use of inorganic fertilizers or combination of organic and inorganic fertilizer as one of the treatments. Hence, the difference between using organic and inorganic fertilizers can be observed. Besides, the types of plants can be changed to different types of plants such as tomato, eggplants and chilli and determine the effectiveness of organic fertilizers on those plants. The main sources of fertilizer also can use various types of fruits and vegetables such as orange peel and banana skin.

REFERENCES

Alias, A. Y. (2010). Amal kitar semula. Berita Harian, Shah Alam.

Alley, M. M. & Vanlauwe B. (2009). The Role of Fertilizers in Integrated Plant Nutrient Management. *Paris: International Fertilizer Industry Association*. Tropical Soil Biology and Fertility Institute of the International Centre for Tropical Agriculture Paris.

Balakrishnan, K. and Pandey, A. (1996). Production of Biologically Active Secondary Metabolites in Solid State Fermentation. Journal of Scientific and Industrial Research, 55: 365-372.

Ayed L.B., Hassen A., Jedidi N., Saidi N., Olfa B., Murano F. (2007). Microbial C and N dynamics during composting of urban solid waste. *Waste Manage Res 25; 24-29.*

Baffi C., Abate MTD., Nassisi A., Silva S., Benedetti A, Genevini P.L., Adani F. (2006). Determination of biological stability in compost: a comparison of methodology. *Soil Biol Biochem 39:1284–1293.*

Balakrishnan, K. and Pandey, A. (1996). Production of Biologically Active Secondary Metabolites in Solid State Fermentation. Journal of Scientific and Industrial Research, 55: 365-372.

Barry, C., 1996. *Nutrient handbook*. Casper publications Pty Ltd, Narrabeen, NSW, Australia.

Beck-Friis, B., Smårs, S., Jönsson, H., Eklind, Y. & Kirchmann, H. (2003). Composting of source-separated household organics at different oxygen levels: Gaining an understanding of the emission dynamics. *Compost Science & Utilization* 11, 41-50.

Bhargav, Samir & Sanjrani, Mumtaz & Javed, Saleem. (2008). Solid-State Fermentatio: An Overview. Chemical & Biochemical Engineering Quarterly ; Vol.22 No.1. 22.

Bojovic B, Stojanovic J. Some Wheat leaf characteristics in dependence of fertilization. Kragujevac *Journal of Science*.2006;28:139–146.

Buchner, B., Fischler, C., Gustafson, E., Reilly, J., Riccardi, G., Ricordi, C., & Veronesi, U. (2012). Food waste: causes, impacts and proposals. *Barilla Center for Food & Nutrition*, 53–61.

Butcher, G. D., & Miles, R. (2012). Concepts of Eggshell Quality, (June), 1–2.

Ch'ng, H. Y., Ahmed, O. H., & Ab. Majid, N. M. (2015). Improving phosphorus availability, nutrient uptake and dry matter production of Zea mays L. on a tropical acid soil using poultry manure, biochar and pineapple leaves compost. Cambridge University Press, pp. 1-19.

Chen, J.-H. (2008). The combined use of chemical and organic fertilizers and/or biofertilizer for crop growth and soil fertility. *Paper Presented at the International Workshop on Sustained Management of the Soil-Rhizosphere System for Efficient Crop Production and Fertilizer Use 16 – 20 October 2006. Land Development Department, Bangkok 10900 Thailand, 2008.*, 1–9.

Cooke JE, Martin TA, Davis JM. Short-term physiological and developmental responses to nitrogen availability in hybrid poplar. *New Phytologist*. 2005; 167(1): 41–52.

Daughtry CST, Walthall CL, Kim MS, Brown De Colsto Un E, McMurtrey JE. (2000). Estimating corn Leaf chlorophyll Concentration from leaf and canopy reflectance. *Remote Sensing of Environment.*;74(2):229–239.

Day M, Shaw K (2000) Biological, chemical and physical processes of composting. In: Stofella PJ, Kahn BA (ed) Compost utilization in horticultural cropping systems. *Lewis Publishers,Boca Raton, USA.*

Dumitrescu, L., Sauciuc, A., Manciulea, I., & Zaha, C. (2008). Obtaining biofertilizer by composting vegetable waste, sewage sludge and sawdust. *Bulletin of the Transilvania University of Braşov Series I: Engineering Sciences*.

Erica Clarissa, Talita Rafaele, Agostini Mantovanni, Juliana Silverira do valle. (2011). Low C:N ratio increases laccase production from basidiomycetes in solid substrate cultivation.Volume:68,page no(295-300).

Fallis, A.. (2013). How To Make and Use Compost. *Journal of Chemical Information and Modeling*, *53*(9), 1689–1699.

FAO. (2015). Food Loss and Food Waste | FAO | Food and Agriculture Organization of the United Nations.

Filho MCMT, Buzetti S, Andeotti M,Arf O, deSa ME.Application times, sources and doses of nitrogen on wheat cultivars under no till in the Cerrado region. *Ciência Rural. 2011;41(8):1375–1382.*

Gaonkar, M., & Chakraborty, A. P. (2016). Application of Eggshell as Fertilizer and Calcium Supplement tablet. *Internacional Journal of Innovatie Research in Science, Engineering and Technology*, 3520–3525.

Garcia, R.A., Rosentrater, K.A., Flores, R.A., 2006. Characteristics of North American meat and bone meal relevant to the development of non-feed applications. Appl. Eng. Agric. 22, 729–736.

Gardiner, D.T. & Miller, R.W. (2008). *Soils in our environment*. New Jersey: Pearson Education Ltd, elevennth edition.

Graves RE, Hattemer GM. (2000).*Environmental engineering national engineering* *handbook: composting*. US Department of Agriculture, Washington, DC. Part 637.

Han, Sun-Kee & Shin, Hang-Sik. (2002). Enhanced acidogenic fermentation of food waste in a continuous-flow reactor. Waste management & research: the journal of the International Solid Wastes and Public Cleansing Association, ISWA. 20. 110-8.

Harsha Sharadchandra Nikos (2015). Eggshell and Bio-waste manure. *International Journal of Scientific & Engineering Research*, Volume 6, Issue 6.

Ismail, S. S., & Manaf, L.A. (2013). The challenge of future landfill: A case study of Malaysia. *Journal of Toxicology and Environmental Health Sciences*, 5(6), 86-96.

Jukka, Lin Chen, Susanna M.,Pirjo K., Veikko H. & Juha H.(2015). Effects of meat bone meal as fertilizer on yield and quality of sugar beet and carrot. *Agricultural and food science*, Vol.24:68-83.

Jones, J. B., Jr., B. Wolf, and H. Mills. 1991. Plant analysis handbook, Micro-Macro Publishing, Inc., Athens, GA, pp. 23-26.

Kathrivale, S., Yunus, M. N. M., Sopian, K., and Samsuddin, A. H. (2003). Energy potention from municipal solid waste in Malaysia. Renewable Energy, 29, 559-567.

Krishna, C. (2005). Solid-State Fermentation Systems—An Overview. *Critical Reviews in Biotechnology*, *25*(1–2), 1–30.

Lawrence, R.A., Jelen, P. and Fedec, P. 1982. Pilot plant extraction of protein from mechanically separated poultry residues. Can. Inst. Food Sci. Technol. J. 15,325.

Lee, S. H., Choi, K. I., Osako and Jong-In Dong. (2007). Evaluation of environmental burdens caused by changes of food waste management systems in Seoul, Korea. *Science of The Total Environment,* 387(1-3) 42-53.

Lin, C. (2008). Meat Bone Meal As Nitrogen and Phosphorus Fertilizer. *October*, (October), 60.

Machado, C.M., Oishi, B.O, Pandey, A. and Soccol, C.R. (2004) Kinetics of Gibberella fujikori Growth and Gibberellic Acid Production by Solid State Fermentation in a Packed-Bed Column Bioreactor. Biotechnology Progress, 20: 1449-1453.

Madhavi Gaonkar, A.P.Chakraborty.(2016). Application of Eggshell as Fertilizer and Calcium Supplement Tablet. International Journal of Innovative Research in Science, Engineering and Technology. Vol. 5, Issue 3.

Mason, L., Boyle, T., Fyfe, J., Smith, T., & Cordell, D. (2011). National Food Waste Data Assessment: Final Report. *Prepared for the Department of Sustainability,* *Environment, Water, Population and Communities, by the Institute for Sustainable Futures, University of Technology, Sydney*, (June).

Mehlich A., (1953). Determination of P, Ca, Mg, K, Na and NH4 by North Carolina Soil Testing Laboratories. Raleigh,University of North Carolina.

Mengel, K and Kirkby, E.A. (1987). Principles of Plant Nutrition. 4th Edition. *International Potash Institute, IPI, Bern, SMntzerland*,pp.685.

Moh, Y. C. and Manaf, L. A. (2014). Overview of household solid waste recycling policy status and challenges in Malaysia. *Resources, Conversation and Recycling* 82: 50-61.

Murphy, J. & Riley. J. R. (1962). A modified single solution method for the determination of phosphorus in natural waters. An. Chem. Acta. 27:31-36.

Neugebauer, M., & Sołowiej, P. (2017). The use of green waste to overcome the difficulty in small-scale composting of organic household waste. *Journal of Cleaner Production*, *156*, 865–875.

Ngapan, S., Ismail, A. R. and Ade, A. (2012). Construction waste management: Malaysian perspective. *Proceeding of the International Conference on Civil and Environmental Engineering Sustainability (IConCEES)*, p. 229-309.

Okareh, O. T., Oyewole, S. A., & Taiwo, L. B. (2014). Conversion of food wastes to organic fertilizer: A strategy for promoting food security and institutional waste management in Nigeria. *Journal of Research in Environmental Science and Toxicology*, *3*(4), 66–72.

Oreopoulou, V., & Russ, W. (2007). Utilization of by-products and treatment of waste in the food industry. *Utilization of By-Products and Treatment of Waste in the Food Industry*, (November), 1–316.

Peech, M. (1965). Hydrogen-ion activity. p. 914-926. In C.A. Black et al. (ed.) Methods of soil analysis. Part 2. Agronomy Monogr. 9. ASA, Madison, WI.

Quarterly. (2008). Solid-State Fermentation : An Overview, (January). Biochemical Engineering. 22(1).

Reddy, K.R., Hodges, H.F. and Mc Kinion, J.M. (1997). Crop modeling and applications: a cotton example Adv. Agron. 59, 225-290.

Reganold, John & M. Wachter, Jonathan. (2016). Organic agriculture in the twenty-first century. Nature Plants. 2.

Robert E. G., Gwendolyn M. H., Donald S. (2000). Chapter 2 Composting. Part 637 Environmental Engineering National Engineering Handbook.

Robinson, T., Singh, D. and Nigam, P. (2001) Solid-state fermentation: a promising microbial technology for secondary metabolite production. Applied

Microbiology and Biotechnology, 55: 284-289.

Roggatz, U., Mcdonald A.J.S. Stadenberg, I. and Schurr, U. (1999). Effects of nitrogen deprivation on cell division and expansion in leaves of Ricinus communis L. *Plant Cell Environ*., 22, 81-89.

Sequi, P., 1996, The role of composting in sustainable agriculture, in: The Science of Composting, M. Bertoldi, P. Sequi, B. Lemmens, and T. Papi, eds., Blackie Academic & Professional, London, pp. 23–29.

Singh RP., 2012. (2012). *Organic Fertilizers: Types, Production and Environmental Impact*. Nova Science Publisher, New York.

Selim S. M., M. S. Za yed, H. M. Atta (2012). *Nature and Science* 10(2).

Subramaniyam, R., & Vimala, R. (2012). Solid State and Submerged Fermentation for the Production of Bioactive Substances : a Comparative Study. *Intenational Journal of Science and Nature*, *3*(3), 480–486.

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

Tan Lih Min.(2015). Production of Fertilizer using Food Wastes of Vegetables and Fruits. Plant Resource Science and Management.

Tanimu, Idris & Mohd Ghazi, Tinia & Razif Harun, Mohd & Idris, Azni. (2014). Effect of Carbon to Nitrogen Ratio of Food Waste on Biogas Methane Production in a Batch Mesophilic Anaerobic Digester. International Journal of Innovation, Management and Technology.

The Sun Daily. 2014. Malaysia waste 8,000 tonnes of food per day.

Trautmann NM, Krasny ME. (1997). Chapter 1: the science of composting, in: composting in the classroom. Cornell University, Ithaca, NY, pp 1–5.

Thi, N. B. D., Kumar, G. and Lin, C. Y. 2015. An overview of food waste management in developing countries: current status and future perspective. *Journal of Environmental Management* 157: 220-229.

Ullio, L. (2003). Eggplant growing. *Agfacts*, *1*(29), 4.

Van Lelyveld LJ, Smith BL,Frazer C.Nitrogen fertilization of tea: effect on chlorophyll and quality parameters of processed black tea. *Acta Horticulturae*.1990; 275:483–488.

Xu, Z., Zhang, F.B., Zhang, L.L., Li, J., 2012. Effects of indigenous and exogenous microbial inocula on dynamic changes of enzyme activities during composting in a bioreactor. *Adv.Mater. Res*. 383–399, 4017–4023.

Ylivainio K., Uusitalo R. & Turtola E.(2007). Meat bone meal and fox manure as P sources for ryegrass (Lolium multiflorum) grown on a limited soil. *Nutrient Cycling in Agroecosystem* 81: 267-278.

Yong, R.N & Yaacob, Wan Zuhairi & Bentley, S & Harris, Chase & Tan, B.K.(2001). Partitioning of heavy metals on soil samples from column tests. Engineering Geology. 60. 307-322.

Zentner RP. (2011). Effects of input management and crop diversity on economic returns and riskiness of cropping systems in the semi-arid Canadian Prairie. *Renewable Agriculture and Food Systems*. 26(3): 208–223.

Zucconi F, Pera A, Forte M, de Bertoldi M (1981). Evaluating toxicity of immature compost. *BioCycle* 22: 54–57.

APPENDIX A

Table A-1: Soil pH during cultivation of key lime (T0R1-T7R1)

TREATMENT	1ST WEEK	2ND WEEK	3RD WEEK	4TH WEEK	5TH WEEK
T0R1	5.77	5.64	5.40	5.32	5.30
T1R1	5.75	5.76	5.77	6.26	6.35
T2R1	5.78	6.50	6.69	6.78	6.88
T3R1	5.80	5.90	6.01	6.26	6.32
T4R1	5.81	6.04	6.12	6.37	6.41
T5R1	5.82	6.15	6.28	6.55	6.60
T6R1	5.79	6.34	6.66	6.71	6.98
T7R1	5.84	6.79	6.83	6.89	6.93

Table A-2: Soil pH during cultivation of key lime (T0R2-T7R2)

TREATMENT	1ST WEEK	2ND WEEK	3RD WEEK	4TH WEEK	5TH WEEK
T0R2	5.83	5.69	5.44	5.50	5.45
T1R2	5.80	5.80	5.81	6.06	6.17
T2R2	5.78	6.13	6.31	6.68	6.88
T3R2	5.82	6.11	6.21	6.55	6.70
T4R2	5.79	6.05	6.18	6.52	6.71
T5R2	5.81	5.97	6.22	6.45	6.86
T6R2	5.79	6.60	6.73	6.80	7.13
T7R2	5.75	5.98	6.12	6.36	6.45

Table A-3: Soil pH during cultivation of key lime (T0R3-T7R3)

TREATMENT	1ST WEEK	2ND WEEK	3RD WEEK	4TH WEEK	5TH WEEK
T0R3	5.75	5.42	5.31	5.45	5.72
T1R3	5.78	5.60	5.50	6.40	6.81
T2R3	5.82	6.54	6.72	7.20	7.56
T3R3	5.80	5.93	5.97	6.51	6.73
T4R3	5.77	6.05	6.27	6.35	6.42
T5R3	5.82	6.13	6.20	6.25	6.53
T6R3	5.85	6.39	6.52	6.61	7.01
T7R3	5.79	5.88	6.04	6.37	6.52

Figure A-1: The growth of key lime plants at harvest (R1, R2 and R3)

Table A-4: Height, leaves, flower ad fruit number of plants (T0R1-T7R1)

		1st week	2nd week	3rd week	4th week	5th week	Percentage of increase (%)
Height number (cm)	T0	73	75	78	79	80	9.59
	T1	80	83	88	90	91	13.75
	T2	81	83	87	90	91	12.35
	T3	79	82	83	84	86	8.86
	T4	72	74	77	79	82	13.89
	T5	74	75	77	79	82	10.81
	T6	72	73	73	77	79	9.72
	T7	75	76	77	80	84	12
Leaves number	T0	64	63	59	55	54	0
	T1	86	86	88	89	90	4.65
	T2	68	69	73	74	76	11.76
	T3	63	64	68	69	70	11.11
	T4	56	59	60	62	63	12.5
	T5	51	51	53	55	56	9.80
	T6	34	34	34	36	38	11.76
	T7	38	38	37	37	39	2.63
		1st week	2nd week	3rd week	4th week	5th week	Number of increases
Fruit number	T0	0	0	0	0	0	0
	T1	0	0	0	1	1	1
	T2	0	0	1	3	3	3
	T3	0	0	0	0	0	0
	T4	0	0	0	0	0	0
	T5	0	0	0	0	0	0
	T6	4	4	4	5	5	1
	T7	4	4	4	4	5	1
Flower number	T0	0	0	0	0	0	0
	T1	0	1	1	0	0	1
	T2	0	3	2	0	0	3
	T3	0	0	0	0	0	0
	T4	0	0	0	0	0	0
	T5	6	6	6	6	6	0
	T6	0	1	1	0	0	1
	T7	10	10	9	10	10	1

Table A-5 : Height, leaves, flower ad fruit number of plants (T0R2-T7R2)

		1st week	2nd week	3rd week	4th week	5th week	Percentage of increase (%)
Height number (cm)	T0	53	55	57	58	59	11.32
	T1	80	84	86	90	93	16.25
	T2	92	94	96	99	104	13.04
	T3	70	71	73	74	76	8.57
	T4	91	93	95	96	98	7.69
	T5	92	93	97	99	102	10.87
	T6	84	84	85	92	93	10.71
	T7	75	76	77	79	84	12
Leaves number	T0	73	73	68	67	65	0
	T1	42	40	43	45	46	9.52
	T2	115	117	117	118	118	2.61
	T3	50	51	55	57	59	18.0
	T4	54	55	56	58	60	11.11
	T5	101	101	103	105	107	5.94
	T6	86	88	89	90	91	5.81
	T7	30	28	27	29	32	6.67
		1st week	2nd week	3rd week	4th week	5th week	Number of increase
Fruit number	T0	0	0	0	0	0	0
	T1	0	0	0	2	2	2
	T2	0	0	1	2	2	2
	T3	0	0	0	0	0	0
	T4	9	9	9	9	9	0
	T5	0	0	0	0	0	0
	T6	4	4	6	6	6	2
	T7	13	13	13	13	15	2
Flower number	T0	0	0	0	0	0	0
	T1	0	2	2	0	0	2
	T2	0	2	1	0	0	2
	T3	0	0	0	0	0	0
	T4	0	0	0	0	0	0
	T5	0	0	0	0	0	0
	T6	9	9	5	6	6	1
	T7	7	7	7	9	6	2

Table A-6: Height, leaves, flower ad fruit number of plants (T0R3-T7R3)

		1st week	2nd week	3rd week	4th week	5th week	Percentage of increase (%)
Height number (cm)	T0	80	82	83	85	86	7.5
	T1	83	85	90	92	93	12.05
	T2	70	73	76	78	79	12.86
	T3	77	78	78	82	84	9.09
	T4	90	93	95	95	97	7.78
	T5	93	95	95	97	100	7.53
	T6	70	72	73	75	78	11.43
	T7	90	93	94	96	99	10
Leaves number	T0	35	30	27	27	26	0
	T1	67	67	68	68	69	2.98
	T2	50	53	56	57	57	14
	T3	51	53	58	62	64	25.49
	T4	84	88	90	91	92	9.52
	T5	80	81	84	85	86	7.5
	T6	22	23	23	25	26	18.18
	T7	29	29	28	29	30	3.44
		1st week	2nd week	3rd week	4th week	5th week	Number of increase
Fruit number	T0	0	0	0	0	0	0
	T1	0	0	0	1	1	1
	T2	0	0	1	2	2	2
	T3	0	0	0	0	0	0
	T4	0	0	0	0	0	0
	T5	0	0	0	0	0	0
	T6	0	2	2	2	2	2
	T7	6	6	8	8	8	2
Flower number	T0	0	0	0	0	0	0
	T1	0	1	1	0	0	1
	T2	0	2	1	0	0	2
	T3	0	0	0	0	0	0
	T4	0	0	0	0	0	0
	T5	0	0	0	0	0	0
	T6	2	2	2	2	2	0
	T7	6	6	6	6	6	0

Table A-7: Selected Chemical Properties of Soil after Pot Experiment (T0R1-T7R1)

Property	Value Obtained							
	T0R1	T1R1	T2R1	T3R1	T4R1	T5R1	T6R1	T7R1
Total OM (%)	4.1	4.6	7.4	4.8	5.2	4.2	5.6	4.8
Total C (%)	2.38	2.67	4.29	2.78	3.02	2.44	3.25	2.78
Total N (%)	0.06	0.08	0.17	0.08	0.20	0.11	0.25	0.14
Available P (ppm)	50	120	180	120	86.67	66.67	66.67	53.33
Exchangeable K (ppm)	101.12	302.48	302.20	213.28	160.4	105.2	229.16	115.68
Exchangeable Al (ppm)	327.4	247.4	131.36	224.6	-1.80	-3.04	-2.92	-4.08
Exchangeable Ca (ppm)	213.40	567.20	3602.4	644.8	4432	4280	5140	4776
Exchangeable Mg (ppm)	27.26	32.97	96.28	59.91	92.80	81.68	95.40	92.72
Exchangeable Fe (ppm)	70.58	44.88	17.95	48.56	0.48	0.46	0.37	0.38
Exchangeable Cu (ppm)	0.93	0.64	0.52	0.79	0.27	0.26	0.28	0.29
Exchangeable Zn (ppm)	1.49	1.88	7.54	2.18	0.19	0.20	0.12	0.22

Table A-8: Selected Chemical Properties of Soil after Pot Experiment (T0R2-T7R2)

Property	Value Obtained							
	T0R2	T1R2	T2R2	T3R2	T4R2	T5R2	T6R2	T7R2
Total Organic Matter (%)	4.0	4.6	7.2	4.8	5.2	4.1	5.6	4.6
Total C (%)	2.32	2.67	4.18	2.78	3.02	2.38	3.25	2.67
Total N (%)	0.06	0.08	0.20	0.11	0.22	0.14	0.25	0.17
Available P (ppm)	60	110	170	110	86.67	60	66.67	40
Exchangeable K (ppm)	85.04	261.92	331.92	289.76	144.98	101.12	215.12	169.20
Exchangeable Al (ppm)	270.9	231.16	89.72	234.04	-3.00	-4.64	-4.68	-6.48
Exchangeable Ca (ppm)	114.4	337.08	4448	1549.6	4908	4760	5576	5140
Exchangeable Mg (ppm)	28.71	36.38	134.36	52.20	97.96	94.32	115.64	98.92
Exchangeable Fe (ppm)	103.5	58.04	6.70	50.90	0.80	0.43	0.36	0.46
Exchangeable Cu (ppm)	1.73	1.13	0.53	0.63	0.35	0.23	0.28	0.40
Exchangeable Zn (ppm)	2.30	2.56	7.76	2.76	0.15	0.12	0.092	0.34

Table A-9: Selected Chemical Properties of Soil after Pot Experiment (T0R3-T7R3)

Property	Value Obtained							
	T0R3	T1R3	T2R3	T3R3	T4R3	T5R3	T6R3	T7R3
Total Organic Matter (%)	4.1	4.6	7.2	4.8	5.2	4.2	5.6	4.8
Total C (%)	2.38	2.67	4.18	2.78	3.02	2.44	3.25	2.78
Total N (%)	0.06	0.08	0.20	0.11	0.22	0.14	0.25	0.17
Available P(ppm)	55	110	172	110	86.67	60	66.67	53.33
Exchangeable K (ppm)	100.10	182.96	302.56	270.84	129.56	103.16	213.28	167.2
Exchangeable Al (ppm)	272.04	145.44	186.56	201.4	-3.68	-3.08	-3.00	-4.12
Exchangeable Ca (ppm)	102.40	186.24	811.2	1118	4976	4380	5134.8	4780
Exchangeable Mg (ppm)	22.54	28.94	39.58	51.56	78.92	75.82	92.42	90.45
Exchangeable Fe (ppm)	87.04	51.46	12.33	49.73	0.64	0.45	0.37	0.42
Exchangeable Cu (ppm)	1.33	0.89	0.53	0.71	0.31	0.25	0.28	0.35
Exchangeable Zn (ppm)	1.90	2.22	7.65	2.47	0.17	0.16	0.11	0.28