EFFECT OF NPK FERTILIZER, FERMENTED FRUIT PEEL WASTE, AND OIL PALM WASTE COMPOST ON THE SOIL FERTILITY, GROWTH AND YIELD OF OKRA (*Abelmoschus esculentus* L.) CULTIVATED ON EX-TIN MINING SOIL

by

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ABSTRACT

EFFECT OF NPK FERTILIZER, FERMENTED FRUIT PEEL WASTE, AND OIL PALM WASTE COMPOST ON THE SOIL FERTILITY, GROWTH AND YIELD OF OKRA (*Abelmoschus esculentus* L.) CULTIVATED ON EX-TIN MINING SOIL

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Ex-mining soil is infertile and cannot retain water and nutrients. Therefore, amending ex-mining soil is important before crops can be planted. To date, there are limited studies in comparing the effect of fermented fruit peel waste (FFPW) and oil palm waste compost on the improvement of soil fertility, growth and yield of crops cultivated on ex-tin mining soil. The objectives of experiment are to evaluate the effect of NPK fertilizer, fermented fruit peel waste and oil palm waste compost on soil fertility of ex-tin mining soil in UTAR, Perak, as well as the growth and yield of okra cultivated on the same soil. Three blocks, each with five plants, are arranged in randomized complete block design (RCBD) subjected to four treatments: control with no fertilizer (T1), 0.1 g/kg soil NPK (15:15:15) fertilizer (T2), 25 mL/kg soil blended and diluted 1:100 fermented fruit peel waste (T3) and 50 g/kg oil palm waste compost (T4). For soil fertility parameters, T4 improved the soil fertility of the ex-tin mining soil by decreasing the soil pH value, increasing soil electrical conductivity, and maintaining the soil organic carbon concentration. For vegetative parameters, T4 showed significant difference ($p \leqslant 0.05$) in increasing the leaf area to average of 615.51±176.96 cm^2, plant height (124.77±32.6 cm), stem diameter (17.02±3 mm), dry plant weight (45.36±15.35 g), dry root weight (19.91±10.41 g) number of flowers (11.67±2.79), total dry pod yield (125.24±21.35 g) and average dry pod weight (2.69±0.31 g) in comparison to other treatments. The results indicated that T4 improved the vegetative growth and yield of okra. The application of oil palm waste compost is recommended for improving soil fertility, growth and yield of crops cultivated on ex-tin mining soil, because organic matter helps the soil to hold nutrients, water and thus, help plants to uptake nutrients easily.

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Lastly, I would like to thank my family for their support. With all these supports, so I can complete the research and thesis.

DECLARATION

I hereby declare that this final year project report is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UTAR or other institutions.

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APPROVAL SHEET

This project entitled “**EFFECT OF NPK FERTILIZER, FERMENTED FRUIT PEEL WASTE, AND OIL PALM WASTE COMPOST ON THE SOIL FERTILITY, GROWTH AND YIELD OF OKRA (*Abelmoschus esculentus* L.) CULTIVATED ON EX-TIN MINING SOIL**” was prepared by NG KAI LI and submitted as partial fulfilment of the requirements for the degree of Bachelor of Science (Hons) Agricultural Science at Universiti Tunku Abdul Rahman.

Approved by:

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Date: 23/12/2022

PERMISSION SHEET

It is hereby certified that **NG KAI LI** (ID No: **18ABD04171**) has completed this final year project entitled "**EFFECT OF NPK FERTILIZER, FERMENTED FRUIT PEEL WASTE, AND OIL PALM WASTE COMPOST ON THE SOIL FERTILITY, GROWTH AND YIELD OF OKRA (*Abelmoschus esculentus* L.) CULTIVATED ON EX-TIN MINING SOIL**" under the supervision of Dr Clement Wong Kiing Fook (Supervisor) from the Department of Agricultural and Food Science.

I hereby give permission to the University to upload the softcopy of my final year project in pdf format into the UTAR Institutional Repository, which may be made accessible to the UTAR community and public.

Yours truly,

Ng

(NG KAI LI)

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ANOVA	Analysis of variance
Al	Aluminum
B	Boron
C	Carbon
C/N	Carbon-nitrogen ratio
Ca	Calcium
Cd	Cadmium
CEC	Cation exchange capacity
cmol_c	centimoles of positive charge
Cu	Copper
EC	Electrical conductivity
Fe	Iron
FFPW	Fermented fruit peel waste
H	Hydrogen
K	Potassium
M	Molarity
Mn	Manganese
N	Nitrogen
nm	Nanometer
O	Oxygen
P	Phosphorus
RM	Ringgit Malaysia
SOC	Soil organic carbon
SP-36	Single fertilizer with 36% phosphorus content
SPSS	Statistic Package for Social Science

T1	Control with no fertilization
T2	NPK (15:15:15) fertilizer
T3	Blended and 1: 100 diluted fermented fruit peel waste (FFPW)
T4	Oil palm waste compost (Baba)
UTAR	Universiti Tunku Abdul Rahman
v/v	Volume per volume
w/v	Weight per volume
Zn	Zinc
μS/cm	Microsiemens per centimeter

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Okra (*Abelmoschus esculentus* L.) is an herbaceous annual crop originated from Ethiopia. Its edible immature fruit or pod is white, soft, and carries rounded seeds. Its flesh is glutinous and contain sticky substance which is rich in polysaccharides, antioxidants and various nutrients (Vakili et al., 2014). Okra is propagated by seeds and has a lifespan of 90-100 days. According to Das, Ramjan and Kumar (2019), in general, the first harvesting of okra pod is between 40-45 days from germination, while the days from flowering to fruiting is 9-12 days. The total yield of okra fresh pods per ha is 10-12.5 tons. In 2020, production of Malaysia fresh okra reached 57,861 tons in 3,804 ha farming land, having 16.1 metric tons/ha average okra production (DOA, 2020).

According to study of Hassan (2015), there are 47% unsuitable farming land in Malaysia. The examples of unsuitable farming land are acid sulphate land, swamp and ex-mining land (sand tailing). Malaysia was the largest tin producer in end of 19th century. The mining industries improved the constructure of railways and infrastructure, boosting Malaysia's economy. However, the tin mining industry collapsed in mid 1980s (Bolan, Kirkham and Ok, 2017). As consequence, 127,550 ha of total area of ex-mining land were left behind in Malaysia (Vimala and Sukra, 2010). An ex-mining land consist mainly of sand or clay and often trap water and form vast ponds or lakes. The properties of sand or clay have a low nutrients holding capacity (Bolan, Kirkham and Ok, 2017).

Ex-mining soil is mostly composed of by-products of tin tailing such as crashed rock, undesired soil materials other than tin material. The sand tailing area is where the excavated undesired soil material is deposited (Vimala and Sukra, 2010). Repurposing of the ex-mining land into residential, recreational or agricultural purpose promises great economic benefits to the country. About 60% of ex-mining soil in Malaysia are rehabilitated or reused for housing, industrial states, animal farming, tourism, and public institution (Vimala and Sukra, 2010). Various crops such as okra, soybean, dwarf long-bean and cucumber were successfully planted on ex-mining land (Lim and Vimala, 2007a; Lim and Vimala, 2007b; Lim and Vimala, 2008a; Lim and Vimala, 2008b; Vimala and Sukra, 2010). However, the soil nutrient content must be maintained or constantly replenished by inorganic or organic fertilizer for optimal plant growth and yield (Weil and Brady, 2017).

There are two main types of fertilizers, which are (i) compound, chemical, mineral or inorganic fertilizers and (ii) or organic fertilizer. The chemical fertilizers are generally regarded as being less environmentally-friendly, however, they are popular in Malaysia due to their apparent effectiveness, and accounting for around 90% of the total use of fertilizers in Malaysia (Chong et al., 2017). Generally, the chemical fertilizers are mainly made from nitrogen (N), phosphate (P) and potassium (K), so it is called NPK fertilizer. Besides that, the organic fertilizer is made from living organisms such as plant residue, or animal waste (Vakili et al., 2014). Examples of organic fertilizer are poultry manure, cow dung, EPB-based compost, fermented fruit peel waste, and empty fruit bunch-based compost.

1.2 Problem Statements

Ex-mining soil is lack of organic matter, which is important for holding water and nutrients (Andika, Gofar and Budianta, 2013; Zipper et al., 2013). Although there some past researches conducted in investigating the effect of NPK fertilizer (Lestari, Apriyadi and Aan, 2019), FFPW (Zhu et al., 2020) and organic fertilizers like rice straw compost (Andika, Gofar and Budianta, 2013) and empty fruit branch (EFB) based waste compost (Inonu et al., 2020) on ex-mining soil. However, these researches were not conducted in the same place or same type of ex-mining soil with same dose and fertigation frequency. Meanwhile, its materials of treatments were also not made by same processing method. Therefore, the findings are less comparable to each others and there are limited studies in comparing the effect of fermented fruit peel waste and oil palm waste compost on the improvement of soil fertility, growth and yield of crops cultivated on ex-tin mining soil.

1.3 Objectives of Study

Hence, this study aims to evaluate the effects of NPK fertilizer, fermented fruit peel waste, and oil palm waste compost on (i) the soil fertility of ex-tin mining soil; and (ii) the growth and yield of okra cultivated on ex-tin mining soil.

CHAPTER 2

LITERATURE REVIEW

2.1 Okra (*Abelmoschus esculentus* L.) and its Production

The okra (*Abelmoschus esculentus* L.) under the family *Malvaceae* with genus *Abelmoschus* is an erect, deep rooted, herbaceous, annual crop, originated from Ethiopia. The leaves are hairy, simple, alternate and palmately 5 lobed, while the pale-yellow flowers are perfect, self-pollinated, solitary and axillary (Figure 2.1 and 2.2) (Ministry of Environment and Forests Government of India, 2011). It is also tolerant to drought, heat, and intermittent moisture, heavy clay among other vegetables. Okra grows best in tropical and warm temperate environment. Nowadays, okra is cultivated commercially in many countries such as Malaysia, India, Western Africa, Japan, and USA (Singh et al., 2014).

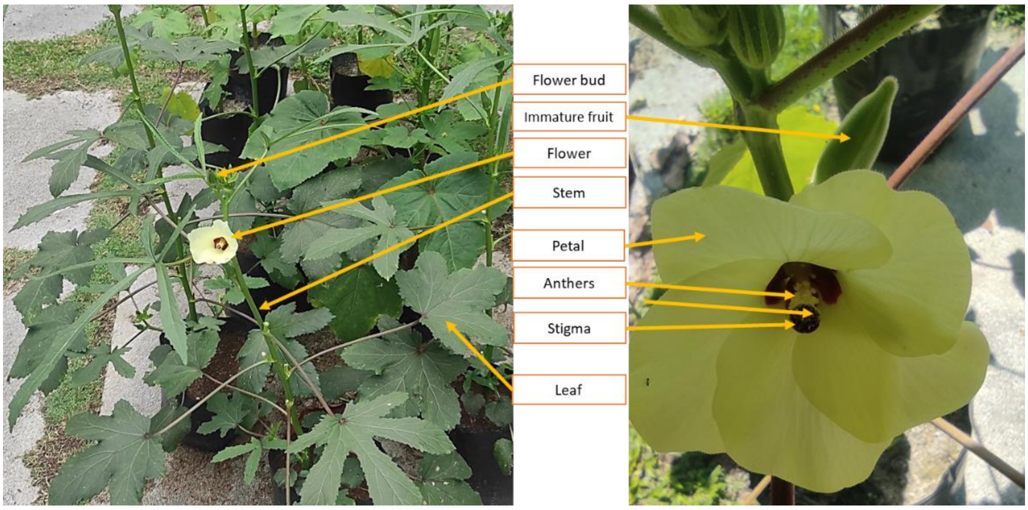

Figure 2.1: The okra (*A. esculentus* L.).

Figure 2.2: Cross section of an okra pod showing its seeds (Ogunbor, 2020).

Okra is the sixth largest production of vegetable in Malaysia in 2020, accounting for the use of 6% of farming area in Malaysia (DOA, 2020). According to Tridge (2020), the production of okra was gradually increasing and reached a peak at 58,200 metric tons in 2019 (Figure 2.3). This was followed by a slight decrease to 57,861 tons in 3,804 ha farming land, having 16.1 metric tons/ha average okra production in 2020 (DOA, 2020).

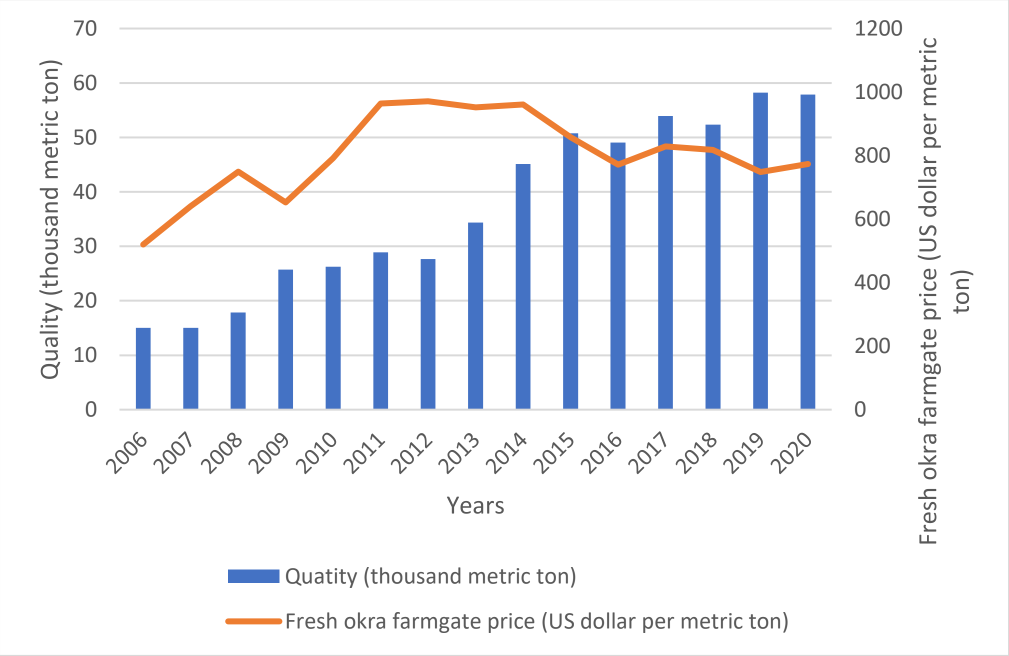

Figure 2.3: The production of fresh okra in Malaysia 2006 – 2020 adopted from Tridge, (2020).

2.1.1 Nutritional Value of Okra

The edible immature fruits or pods of okra have white, soft, and round seeds and its fleshes are glutinous containing sticky substance (Figure 2.2) (Ministry of Environment and Forests Government of India, 2011). In accent, okra was noticed by Egyptians due to its dietary benefits in human digestive system to prevent kidney stones. It was used as natural folk medicine in aspect of diuretic, gastroprotective and antiulcerogenic agents. Other than that, the Asian and African use its mucilage as traditional treatment for gastritis and gastric ulcers. The mucilage contains polysaccharides, which also can be used to thicken soup, or used as fat substitute and egg substitute in bakery and making dessert (Gemede et al., 2014; Singh et al., 2014).

The acceptance of okra for use in modern medicinal agent was initiated by the book of a pharmacist called “J.M. Nickell’s Botanical Ready Reference” in 1880. In the book, the okra was the first time to be mentioned in list of drugs and medicinal agent (Bauman and Porter, 2014; Nickell, 2018). Okra pod is found to have numerous secondary metabolites and natural antioxidants like chlorophyllin, quercetin, and α-tocopherol. These antioxidants were reported to have anti-microbial and anti-inflammatory properties, which help to improve the health of patients with chronic diseases (Gemede et al., 2014; Singh et al., 2014). A 100 g of fresh okra pods was reported to contain 1.7 g of fibre, 36 kcal calories, low fat with 0.2 mg and high carbohydrates of 8.2 g as well as 0. 6 mg of vitamin B3, 0.04 mg of vitamin B1, 47 mg of vitamin C, carotenoids 185 mg, iron 1.2 mg and calcium 84 mg (Singh et al., 2014). In short, it is a cost effective and safe nutrients source for human health (Scartezzini and Speroni, 2000).

2.1.2 Growth of Okra

According to Charrier, (1984) and Ministry of Environment and Forests Government of India, (2011), the *A. esculentus* (L.) have widest geographical distribution in the world among other species in genus *Abelmoschus* like *A. ficulneus*, *A. tuberculatus*, and *A. moschatus*. Within the species of *A. esculentus* (L.), The “Pusa Sawani” (India) and “Clemson Spineless” (USA) are the well-known okra cultivar in the world (CABI, 2022), and there is no significant difference in case of yield of crop between two cultivars (Khan et al., 2002). The okra is propagated by seeds and has a lifespan of 90-100 days. The first harvest of pod is between 40-45 days from germination, and 9-12 days from flowering to fruiting. The total yield of okra fresh pods per ha is 10-12.5 tons (Das, Ramjan and Kumar, 2019). However, the okra continuous flowering is strongly affected by variety, biotic and abiotic stress, such as soil moisture, soil fertility, and continuous harvesting pod stimulation (Ministry of Environment and Forests Government of India, 2011). For clarifying purpose and easy for comparison in the continual explanation of this paper, the okra species for all the referred articles or papers in this paper is *A. esculentus* (L.).

2.2 Soil-plant Relationship, Soil Compositions and Ions

Soil has three-phase system, which are solid, liquid and gas. The liquid phase (soil solution) is water between the soil particles that contains several materials such as soluble organic compound, gases and ions (Chesworth, 2008). The organic is termed as any chemical compound that have carbon bonds. Since plants mainly obtain the nutrients through its roots, soil nutrients supply to plant at root zone is a dynamic process. The nutrients (cations and anions) are absorbed from soil solution by root, a small quantity of ions (HCO_3^-, H^+, and OH^-) are released back to the soil solution by plant at the same time. The ions (cations and anions) in soil solution and plant root cell solution must be maintained in equilibrium (Havlin et al., 2017; Weil and Brady, 2017). Hence, as the plants take available ions from soil solution, the soil nutrients level decreases. The ions that are adsorbed on the surface of soil particles (clays, organic matter fragments) will be released to replenish the soil solution. However, not all the ions are always in soluble and available form for the plants. There are also numerous environmental factors (soil air, soil microbes, and weathering effect), parental soil materials, and human activities can affect presence and concentration of ions in the soil solution, especially in the case of H, C, N, K, and P ions.

The soil organic matter is termed as all the organic components of soil: (i) living organisms (plant, animal tissues and microorganisms), (ii) plant residues (dead plant materials in various decaying process) (iii) dissolved organic biomolecules (amino acid, enxymes) (iv) microaggregates that is unidentifiable about its source (charred condition) (Weil and Brady, 2017). The soil organic matter is not equal to the soil organic carbon used in this study. The soil total carbon is classified into two types, which are inorganic carbon and organic carbon. The inorganic carbon is contributed by mineral carbonate in the soil parental material whereas the organic carbon (OC) is the fragments of organic matter contributed by any living organisms, like plant residue, animal waste, and soil microbes included earthworm, rhizophores, and nematodes (Weil and Brady, 2017). In other words, soil organic carbon (SOC) is the carbon component of organic matters (Edwards, 2019).

A plant is composed by 6% of H, 45% of C, 1.5% of N, 0.2% of P and 1% of K (Havlin et al., 2017). In plant, the carbon compounds also bind to other ions or elements like O, H, N, and P, forming the simple sugar, amino acids, and fatty acid. Due to the strong bonding between ions or elements and carbon compound, the decomposition of organic matter by microbes take time to break down the components of organic matters like lignin, cellulose and resin (Bot, Benites and Rome, 2005). The C content in a typical plant dry matter is between 40-45%, which is higher than N content (<10%). Be that as it may, the nitrogen is also indispensable element for plants. No creature can obtain energy and build essential organic compounds for life process on carbon alone. The insufficient of accessible nitrogen will cause the competition between plants and soil microbes (Havlin et al., 2017; Weil and Brady, 2017).

N is a key element as the building blocks of protein. For instance, the chlorophyll that converts light into chemical energy is composed by four pyrrole rings with one N and four C atoms. Lacking N in plants will lead to carbohydrate deposition in vegetative cell, yellowing leaf veins, leaf chlorosis, and increase susceptible of plants disease. Plants prefer nitrate (NO_3^-) and ammonia (NH_4^+) (Havlin et al., 2017; Weil and Brady, 2017). To provide sufficient N, farmers can use inorganic N fertilizers like urea and urea ammonium sulphate. The N fertilizers directly release NO_3^- and NH_4^+ into the soil solution, however it depends on the type of fertilizers. On the contrary, if a plant or animal residue is applied to the soil, the organic N is firstly mineralized into NH_4^+ by soil microbes and further converted into NO_3^- through nitrification, eventually be added into soil solution (Havlin et al., 2017). Organic N can present in combination with lignin, clays and amino acids. As the soil organic matter increasing, the soil total N is also increased (Palmer et al., 2017). During these processes, NO_3^- can be reduced and lost to ground water through percolating water below the root zone and the NH_4^+ concentration in soil solution can be reduced due to the fixation of NH_4^+ with clay mineral or other soil particles as well as the microbial conversion of NH_4^+ back to the organic N for soil microbes' self-utilization under N resource restricted condition (Havlin et al., 2017).

P is the essential element in plant. The adenosine triphosphate (ATP) transfers $H_2PO_4^-$ molecules to the energy-requiring substances in plant, facilitating the chemical and biological reaction in cells. The plant P deficiency will result necrotic, dark spots and purple coloration on old leaf. To prevent that, input P through fertilizers could be the solution. The examples of the inorganic P fertilizer are diammonium phosphate, ammonium polyphosphate, and urea ammonium phosphate (Havlin et al., 2017; Weil and Brady, 2017). When P fertilizer dissolved into the soil solution, it will directly form as $H_2PO_4^-$ or HPO_4^{-2} ions. Meanwhile, if a manure or compost is applied to the soil, its P content in form of organic P compound such as nucleic acid and phytin which will be converted to $H_2PO_4^-$ ions by rhizosphere later, and the ions will be added into the soil solution. Plants prefers to absorb $H_2PO_4^-$ or HPO_4^{-2} ions, so the ions are directly available for the plants. However, P can be unavailable to the plant due to the adsorption on clays or mineral surface as well as binding with Ca, Fe, Al that will form solid mineral P, that called immobilization of P (Bolan, Adriano and Naidu, 2003; Havlin et al., 2017). Difference source of P fertilizers have proportion of soluble P. For example, animal wastes have 25-80% of water-soluble P in total P content. Hence, during raining, the water infiltration brings the soluble P down through the soil profile. Since P is more strongly adsorbed to clays compared to sand, because of the difference in P adsorption capacity, the unabsorbed soluble P still can be leached through groundwater and surface water in case of macropore water flow and surface runoff (Havlin et al., 2017).

Unlike the C, N, and P that take parts in structure of organic compound, K is not the main building block of biochemical compound, it remained as ions form in cells, involves in balance of cellular osmotic pressure, and transport of photosynthesis products. K deficiency will result in chlorosis and necrosis of lower leaf edges as well as increasing susceptibility of bacterial, fungal, viral and nematode infestations. Examples of inorganic K fertilizers are potassium chloride, potassium sulfate and potassium nitrate v (Havlin et al., 2017; Weil and Brady, 2017). The fertilizer can directly provide K to the soil solution in form of K^+, which is same as the decomposition of organic matter. K is more readily to be leach than phosphorus. A highly weathered soil will have low K content, especially in the tropical regions (Havlin et al., 2017).

In short, to increase the soil available ions and promote plant growth, addition of nutrients or ions must be added to the soil solution (Havlin et al., 2017). For that purpose, there are mainly two types of fertilizer, which are (i) compound, chemical or mineral fertilizers and (ii) organic fertilizers.

2.3 Ex-Mining Soil in Malaysia and its Soil Feature

According to study of Hassan (2015), there are 47% unsuitable farming land in Malaysia. The examples of unsuitable farming land are acid sulphate land, swamp and ex-mining land (sand tailing). The sand tailing is the by-product of mining of natural resource. In the early 19th century, mining was one of the major industries of Malaysia (Agus et al., 2017). By 1883, the British Malaysia was the largest tin producer and supported 55% of the world's tin demand in the end of 19th century. Tin was one of the highly demanding minerals in the world. However, in 1985, the dropping of tin's price from RM 29 per kg to RM 15 per kg and rising of fuel cost, the tin mining industry collapsed in mid 1980s and the tin mining activities was greatly reduced. Despite the benefits in nation's economy and building of vital infrastructure such as railways, brides, administrative center, institutions, temples and telecommunications, the tin mining has left the Malaysia with environmental problem (Bolan, Kirkham and Ok, 2017). There are 127, 550 ha of total area of ex-mining land in Malaysia. The Perak state accounts for 63% (71,850 ha) of the tin-tailing area, followed by Selangor and Kuala Lumpur (28,250 ha) (Vimala and Sukra, 2010).

The mechanism of tin mining process is by using the purification method based the different weight of the excavated soil to separate the tin ore from other soil material. The main practiced purification method is gravel pump mining and dredging. Taking gravel pump mining method as example, the tailing area is located at the end of palung. The palung is a downward wooden structure with sloping down channel and crossing bar. The extracted soil will enter palung. The heavier soil material will deposit in the first. Hence, the tin ore will be left in the palung and harvested by workers, Then, the soil tailing (stones, clay and quartz) will be washed away by the water flow (Agus, et al., 2017) toward sedimentation pond. Since, there are three types of tailings which are gravel, sand, and slime. The tin sand tailing is defined as the deposited, unwanted sand other than tin material producing from the mining process. The sand tailing area is where the excavated sand deposited on (Vimala and Sukra, 2010).

The recent mine dumps or sand tailing is classified as Entisols (Pashkevich, Bech and Bini, 2017). Entisols is a soil type classified by USDA soil taxonomy, it has no special diagnostic horizons (Mylavarapu, Harris and Hochmuth, 2016). The diagnostic horizon is the presence or absence of characteristic natural soil layers in soil. Formation of entisol may occur on man-caused mixture of soil original horizons, or on steep with soil erosion that results construction of soil from the segregated soil (Weil and Brady, 2017).

An ex-mining land may consist of ponds surrounded with sand or clay. The high content of sand or clay cause the sand tailing to have a low water and nutrients holding capacity (Vimala and Sukra, 2010; Weil and Brady, 2017). Hermansyah et al., (2021) found that the sand tailing will have different soil characteristic after the years from mining. For example, the ex-coal mining soil had 7.2 soil pH before mining, 4.19 pH value after 5 years from mining with vegetation and 4.82 pH value after 10 years from mining with vegetation. The improvement of soil pH was caused by the natural revegetation. From 5 years from mining with vegetation to 10 years from mining with vegetation, the organic matter, CEC, available P, Fe contents, Mn contents increased, however the total N, total K decreased. Overall, the ex-tin mining soil was found to have low organic carbon, low available and total N, P, K, Mg, Ca, toxic level of Cu, B, Zn, and Cd (Andika, Gofar and Budianta, 2013; Oktavia, Setiadi and Hilwan, 2015; Agus et al., 2017; Zuhaidi et al., 2022).

2.3.1 Potential of Using Ex Mining for Agriculture

Repurposing unproductive ex-mining land into residential, recreational and agricultural purpose promise great economic benefits to the country. About 60% of ex-mining soil in Malaysia are rehabilitated or reused for purpose of housing, industrial states, animal farming, tourism, public institution (Vimala and Sukra, 2010). Various crops such as soya bean, okra, dwarf long-bean, cucumber, chili, egg plants, sweet corn, lemon grass and ginger were successfully planted on ex-mining land (Lim and Vimala, 2007a; Lim and Vimala, 2007b; Lim and Vimala, 2008a; Lim and Vimala, 2008b; Vimala and Sukra, 2010). However, the soil nutrient content must be maintained or constantly replenished by inorganic or organic fertilizer for optimal plant growth and yield (Weil and Brady, 2017). Moreover, the iron-mining pit lakes in Minnesota were used in aquaculture activities such as culture salmonids. The lake created 44 million US dollars per year (Axler et al., 1992) for the manager. Besides that, in Malaysia, some companies like Mua Hin Farm Sdn. Bhd. in Kampar utilizes the ex-tin mining lakes to do duck farming that same as many smallholders in Malaysia.

2.4 Compound, Chemical or Mineral Fertilizers Used in Agriculture

Chemical fertilizer refers to NPK fertilizers, the fertilizer that contain 3 major nutrients: nitrogen (N), phosphate (P) and potassium (K). The example of chemical fertilizer used in Malaysia are ammonium sulphate, urea, urea ammonium sulphate, ammonium phosphates, phosphate rocks, potassium nitrate, and potash. The chemical fertilizer accounts for around 90% of fertilizer use in Malaysia. (Chong et al., 2017). The total fertilizer application in Malaysia increased from 1983 (496.7 kg/ha) to 2020 (1952.1 kg/ha) (FAO, 2022). Meanwhile, Statista Research Department (2022), it reported that the sale value of synthetic fertilizers in Malaysia reached 4.97 billion Malaysian ringgit in 2021 (Figure 2.4).

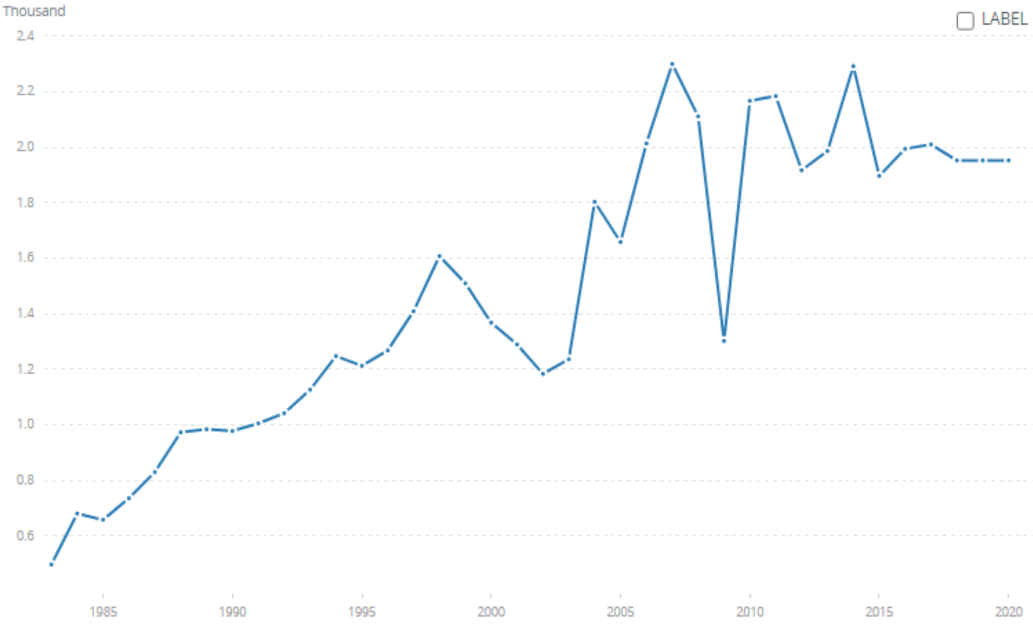

Figure 2.4: Fertilizer application in measurement of kilograms per hectare of arable land in Malaysia.

2.4.1 Effect of NPK Fertilizers in Improving Soil Fertility, Plant Growth and Yield Cultivated on Ex-Mining Soil

According to Vimala and Sukra (2010), the okra (cultivar is not mentioned) planted on sand-tailing of an ex-mining area (mining types not mentioned) with the application of a compound NPK fertilizer (12:12:17:2) will have a first picking of pod at around 52 days from sowing, days from flowering to fruiting is 5-7 days. The fresh pod yield of reached highest of 3t/ha per harvest time and its cumulative yield of okra reached close to 20t/ha at 91-days after sowing (Lim and Vimala, 2007a; Vimala and Sukra, 2010). Other than that, in the case of *Acacia mangium* planted on ex-limestone mining soil, the 15g NPK fertilizer (NPK ratio not mentioned) had proven that it can significantly increasing the plant stem diameter 75% larger than control, and 145 % more number of root nodule compared to control. Meanwhile, the treatment with coconut shell charcoal and NPK fertilizer had 263% more nitrogen content, 143% more phosphate content compared to control. Then, the soil with coconut shell charcoal and NPK fertilizer also had a high cation exchange capacity (CEC) (35.09 me/100g) compared to control (36.01 me/100g) (Wasis, Ghaida and Winata, 2019). The NPK fertilizer (urea dose of 300 kg/ha , potassium chloride with 200 kg/ha, and SP-36 with 150 kg/ha) applied on ex-tin mining land with sorghum also significantly improved the number of leaves, shoot fresh weight, and root dry weight compared to control (Lestari, Apriyadi and Aan, 2019). The NPK fertilizer with 300 kg/ha of urea, 200 kg/ha of triple superphosphate, and 150 kg/ha of potassium chloride also significantly increased the maize plant height from 44.4 cm to 106.7 cm, stem diameter from 3.9 cm to 8.9 cm, yield production from 0.0967 tonnes/ha to 2.4 tonnes/ha, seed dry weight from 3.2 g to 53.5 g on ex-tin mining land (Lestari, Apriyadi and Hartina, 2020). These articles had proven that NPK fertilizer can promote the growth of *Acacia*, sorghum and maize on ex-tin and limestone mining soil.

2.4.2 Advantages and Disadvantages of NPK Fertilizers

Chemical fertilizers are soluble and quick-release fertilizer (Prasanna, 2022). It contains saturated macronutrients, boosting the plant nutrient absorption to have higher production per hectare of farming land. Due to its cheap price of NPK fertilizer, it used as short-term solution for the poor farmer to increase yield (Adekiya et al., 2020). NPK fertilizers can also be used for soil adjustment as different NPK fertilizers vary in acidity level (Haifa Negev technologies LTD, 2022; Prasanna, 2022). Regarding disadvantage of NPK fertilizer, over-application of chemical fertilizer will result negative result like nutrients leaching, acidification, ground water pollution. It will also lead to reduction of life within the soil, many of which are important in maintaining the quality and properties of a good soil. The chemical fertilizer can enhance physiochemical reaction and decomposition of organic matter (Alimi et al., 2007; Roba 2018). Without the organic matter input to soil, the soil compaction and degradation of soil structure, nutrient leaching and erosion will happen, greatly reducing fertilizer efficiency with each use (Roba, 2018).

2.5 Organic Fertilizer Used in The Agriculture Sector

Organic fertilizer is type of fertilizer that composed of plant residue, or animal waste. Organic materials or matter is an aggregation of carbon-based compound, which can be sourced from empty fruit bunch (EFB) and palm oil mill effluent (POME) from oil palm industry, animal body and waste from meat producing industry, rice straw compost, litter compost, fermented fruit peels waste and kitchen compost to produce compost and replenish soil fertility (Vimala and Sukra, 2010).

Different organic materials, processing method, and composting stage will have different nutrients content in the organic fertilizer (Baron et al., 2019). For example, tobacco waste found to have 11 of C/N ratio with a pH of 9.5 (Kayikçioğlu and Okur, 2011) and oil palm frond with cow dung at 3:1 ratio found to have 24.4 of C/N ratio (Vakili, Haque and Gholami, 2012). Besides that, the EFB-based compost has 0.6% of N, 0.06% of P, and 1.92% of K per dry weight. The poultry manure has 1.72% of N, 1.82% of P and 2.18% of K per dry weight (Vimala and Sukra, 2010). Hence, the EFB-based compost and poultry manure have lower NPK nutrient level compared to NPK (15:15:15) fertilizer (15% N, 15% P, 15% K).

2.5.1 Fermented Fruit Peels Wastes (FFPW)

Fruits peel from the citrus family included lemon, lime, sweet orange, and mandarin orange (Stone, 2017) are common kitchen waste in daily life. It is one of the materials used to make fermented fruit peel waste (Pathak, Mandavgane and Kulkarni, 2017). Undoubtably, other materials such as potato peel, dragon fruit peel, vegetable leaves also can be used to make fermented waste. The fruit peel consists of soluble and insoluble carbohydrate, fiber and various essential oils. According to Pathak, Mandavgane and Kulkarni (2017), the fresh orange fruit peel has an average of 6.19% H, 38.91% C, and 1.15% N with mainly 42.5% of pectin, 16.9% of total sugar and 10.5% of hemicellulose. Other than that, fruit peel was also reported to have potential for producing bioethanol as an alternative fuel of gasoline while it also can be used as animal feed, or organic fertilizer to improve soil fertility (Grohmann, Cameron and Buslig, 1996; Pathak, Mandavgane and Kulkarni, 2017; Ricci et al., 2019). As one of the organic fertilizers, the fermented fruit peel waste also called the homemade enzyme, eco-enzymes, or garbage enzymes. Generally, the formula for the homemade enzyme is 1 part of brown sugar, 3 part of waste, and 10 parts of water (Othman, 2013). There 2 main states of fermentation, which are soil state fermentation (low humidity fermentation with selected microorganism and substrate) and submerged fermentation (high humidity fermentation replying on the natural existing microorganisms) (Othman, 2013). Throughout the fermentation, the bacteria convert raw material into acetic acid through various enzymes such as lipase, amylase, and protease at the end of fermentation process, so the product is highly acidic (Othman, 2013; Rasit, Lim and Ghani, 2019).

2.5.2 Effect of Fermented Fruit Peels Waste in Improving Soil Fertility, Plant Growth and Yield Cultivated on General Soil and Lead-Zinc Mining Land

There is limited study of fermented fruit peels waste tested on ex-mining soil, however their performance is better documented on normal soil and were shown to be able to improve plant growth and yields. The fermented apple peel, dragon peel and eggplant peel waste diluted with 1:800 ratio was reported to increase soil organic matter (SOM) from around 18 g/kg soil to more than 40 g/kg soil and total N per kg soil from 1.61 g/kg to 4.27 g/ka as the frequency of irrigation increased (Tong and Liu, 2020). The application of 1:100 dilution fermented fruit peel waste (fruit type not mentioned) can also improve *Turi* plant height from 81.2 cm to 101.6 cm, leaf width from 0.4 cm to 0.6 mm, stem diameter from 12.6 mm to 14.2 mm, and number of leaves from 2009.6 to 2609.8 (Sinulingga et al. 2021). The fermented fruit peel waste made by orange and vegetable peels (dilute ratio not mentioned) can significantly increase lettuce height from 32 cm to 33.63 cm, number of leaves from 11.75 to 18.75 and dry weight from 1.08 g to 6.07 g (Wiswasta, Sukerta and Yuliandewi, 2018). There is only one articles discussed about the fermented fruit peels waste tested on ex-mining soil. The fermented kiwifruit peel waste with 1:800 diluted ratio promoted the root length of castor soil plant 2.09 times longer than its control with no fertilizer on ex lead-zinc mining land (Zhu et al., 2020). A handful of studies had proven that the fermented fruit peel waste can increase growth and yield of crops.

2.5.3 Effect of Other Plant-Based Organic Compost in Improving Soil Fertility, Plant Growth and Yield Cultivated on Ex-Mining Soil

The rice straw compost significantly increased soil pH from 5.4 to 5.57, organic carbon from 1.10 g/kg soil to 1.50 g/kg soil , cation exchange 1.58 cmol_c/kg to 1.78 cmol_c/kg, and total N from 0.1g/kg soil of ex-tin mining soil (Andika, Gofar and Budianta, 2013). The application of EFB-based compost significantly improved the production of eggplants compared to NPK fertilizer (16:16:16) on ex-tin mining land (Inonu et al. 2020). Meanwhile, the chicken manure, cow manure, and litter compost (plant species not mentioned) also increased total N 883%, organic C 272%, CEC 251%, available P 6069% and available K 429% higher compared to the control. Meanwhile, chicken manure also significantly increased plant height (90.2 cm) , root length (58.8 cm), weight of biomass (487.22 g) of Trembesi cultivated on ex-coal mining land compared to NPK fertilizer (50.4 cm, 40.6 cm, 172.40 cm) and control (35 cm, 40 cm, 133.98 cm) at 90 days after planting (Sumaryono et al., 2017).

2.5.4 Advantages and Disadvantage Organic Fertilizers

The decomposing of organic matter slowly provides nutrients and minerals to the soil. The slow process in releasing nutrients can prevent overfertilization and reduce nutrients leaching (Adekiya, 2017; Adekiya et al., 2020). Meanwhile, the organic fertilizer had less harmful effects on the ecosystem. The organic matter is the food of beneficial soil microbes and organism like earthworm and nitrifying bacteria that helps in converting immobile ions to more available forms for plant uptake. The movement of soil organisms can improve the soil drainage and air circulation, enhancing soil structure (Weil and Brady, 2017; Adekiya et al., 2020). The study of Hwang et al., (2019) stated that the application of organic fertilizer can decrease the bulk density of soil to 2-6% and 11-14% over the NPK fertilizer and control.

Other than that, organic fertilizer increases the organic matter in soil with low organic matter due to prolonged cultivation or erosion. The organic matter can preserve the moisture in soil, facilitating the soil biochemical reaction and growth of soil microbes and plant roots (Tadesse and Assefa, 2019). Since organic matter consists numerous complex compounds and substances, its nutrients supply is more balanced compared to chemical fertilizer (Roba, 2018).

Regarding the disadvantages of organic fertilizer, the organic fertilizer has a low nutrient content or NPK content per weight compared to chemical fertilizer. Hence, a large volume of organic fertilizer is needed to supply enough nutrients. Due to the composting methods and materials of organic fertilizers, the nutrients content of compost may not be same and variable (Vimala and Sukra, 2010). The cost of organic fertilizer is also higher than chemical fertilizer. In heavy and long-term application of organic fertilizer, the soil may result heavy metal accumulation (Gong et al., 2019). If the organic fertilizer is not fully fermented or processed, these is a pathogenic transferring risk to humans and animal (Vimala and Sukra, 2010; Roba, 2018).

CHAPTER 3

METHODOLOGY

3.1 Materials, Chemicals and Equipment

3.1.1 Materials

The list of the used materials is showed in Table 3.1.

Table 3.1: Materials used in this study.

Materials	**Specifications / Brand**
Concentrated sulfuric acid 37% v/v	Fisher Scientific band
Ex-tin mining soil	from Universiti Tunku Abdul Rahman (UTAR) Agricultural Park
Four packs Compost	Baba band [a]
Fermented fruit peel waste	Made by mandarin orange peels and brown sugar [a]
NPK (15:15:15) fertilizers	Twin Arrow band [a]
Okra seeds (*Abelmoschus esculentus* L.)	(Baba) VE-022
Plant nursery polybags	16 x 16 cm
Potassium dichromate	Bendosen band
Sucrose	Bendosen band
Transparent plastic bags	N/A
Pesticides: fipronil 5% w/v	FIPEST 5SC band [a]
Water	N/A

* N/A: Not applicable.

[a] refers to Appendix A for detail information.

3.1.2 Apparatus

The list of the used apparatus is showed in Table 3.2.

Table 3.2: Apparatus used in this study.

Materials	Specifications / Brand
Analytical Balance	Kern band Model: ML304T
Beakers	50 mL, 100 mL, 250 mL, 500 mL
Black cloth	N/A
Blender	Nippon band
Cork borers	0.7 cm, 1 cm diameter
Digital caliper	Mitutoyo band
Drying and heating oven	BINDER band
Genesys 10s UV-VIS Spectrophotometer	Thermo Scientific band
Gloves	N/A
Horticultural trimmers	N/A
Knifes	N/A
Permanent markers	N/A
pH meter	Mettler Toledo band FiveEasy series
Plastic cuvettes	2.5 mL size
Plastic stirrer	N/A
Plastic trays	N/A
Portable electrical conductivity meter	Model: YQ10090
Portable weighing balance	Camry band Model: EI-02HS
Precision balance	Mettler Toledo band Model: ME1002
Scoopers	N/A
Soil augers	N/A
Stirrer	N/A
Tap measure	N/A
Tap water	N/A
Woven wire mesh sieve	2 mm mesh size

* N/A: Not applicable

3.2 Planting Site and Experimental Design

The experiment was conducted at an open area between Block D and E (4° 20' 17.9232" N, 101° 8' 37.1904" E) in UTAR. A total of 60 plants was arranged with randomized complete block design (RCBD) with 3 blocks (Figure 3.1). A total of 5 plants were placed within 0.9 m × 0.9 m stones tiles, with each 15 cm aways from each other. Three blocks arranged in randomized complete block design (RCBD) with five plants (Figure 3.1), and four treatments were included in this study: control no fertilizer (T1), 0.1 g/kg soil NPK (15:15:15) fertilizer

(T2), 25 mL/kg soil blended and diluted 1:100 fermented fruit peel waste (T3) and 50 g/kg oil palm waste compost (T4). The detail of treatments was showed in Table 3.3.

Fourteen days after germination, T2 and T3 were applied every 14 days. The 14-days-frequency application of T4 was changed to every 28 days for first two months due to the slow decomposition of treatment's organic matter and the limited soil surface of polybags with okra plants after second application (Day 56 of cultivation).

Table 3.3: Fertilizer treatments used in this study.

Treat-ments	Description	Dose	Applying methods	Ingredients
T1	Control (no fertilization)	-	-	-
T2	NPK (15:15:15) fertilizer	0.1 g/kg soil (Jallow, Sey and Manneh, 2021)	Top dressing	-
T3	Blended, 1: 100 ratio diluted and 2 months room of temperature fermented fruit peel waste (Sinulingga, et al., 2021)	50 mL/kg soil	Soil drenching	Mandarin orange peel, brown sugar, water
T4	Oil palm waste compost (Baba)	350 g/plant each time (5%) (Pérez et al., 2021)	Top dressing	Oil palm meal and fibrous plant materials

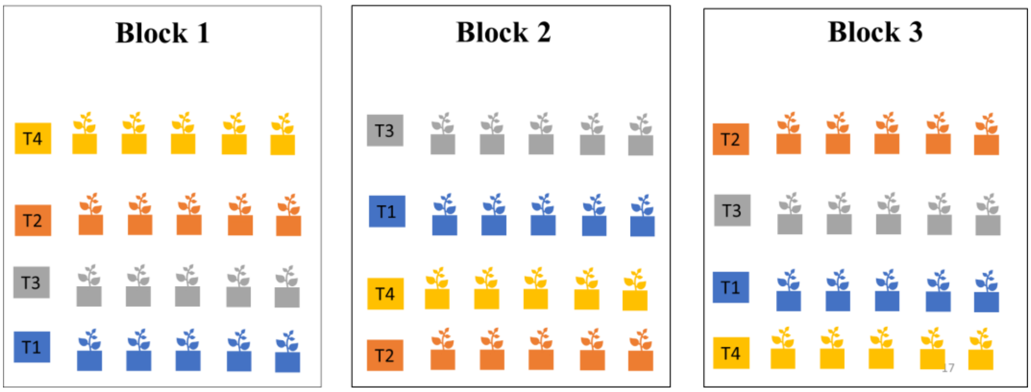

Figure 3.1 The experimental design on the field with RCBD.

Each polybag was filled with approximately 7 kg ex-tin mining soil from UTAR Agricultural Park (4° 20' 34.6416" N, 101° 8' 23.5176" E). Total of sixty polybags were filled with ex-tin mining soil, while 3 seeds were put in into each polybag. The plants were watered daily and when needed, each time until the water leaching from the bottom holes of polybags. Thinning and treatments were conducted after 14 days from the germination leaving only one plant in each polybag. Removing exogenous roots from the bottom of polybags to prevent the absorption of nutrients outside the polybags and inconsistency of result data. Meanwhile, the wilted or dropped leaves were also be removed when needed. The pesticide was prepared by mixing 1 mL fipronil 5% w/v with 1 L tap water, the application of pesticides was applied only one-time throughout the experiment.

3.3 Soil Chemical Analysis

3.3.1 Soil Sampling

Soil samplings were conducted on Day 30 and 90 of cultivation. Five replicates of 10 cm soil were obtained using soil cork borers before being pooled together. The collected soil was stored in plastic bags at room temperature for subsequent soil analysis on the soil pH and electrical conductivity, as well as soil organic carbon concentration.

3.3.2 Soil pH and Electrical Conductivity (EC)

Five grams of air-dried and passed with 2 mm mesh size woven wire mesh sieve soil were added to 12.5 mL of distilled water and the soil mixture was thoroughly mixed. After that, the mixture was left aside to stand for 15 minutes before the soil pH and EC were recorded by using pH and EC meter (Universiti Tunku Abdul Rahman, n.d).

3.3.3 Soil Organic Carbon Concentration (SOC)

Soil organic carbon was tested by using the Walkley-Black method (FAO, 2019) and moisture correction factor was determined according to Bashour and Sayegh (2007). To prepare a sucrose standard curve, different concentrations of sucrose solution were made according to Table 3.4. Two mL of potassium dichromate (0.34 M) solution were added and mixed to each tube. Five mL sulfuric acid were added, cooled and let stand for 30 minutes. After that, 18 mL of distilled water to the tube were added and let stand for overnight. The absorbance of the calibration standards and samples were read in a spectrophotometer set at 600 nm wavelength.

After that, a total of 0.5 g air-dried and passed with 2 mm mesh size woven wire mesh sieve soil was weighed, and 2 mL 10% w/v (0.34 M) potassium dichromate solution were added into it and mixed. After that, 5 mL sulfuric acid 37% v/v were also added into the mixture. The mixture was cooled and stand for 30 minutes. Then, 20 mL distilled water were added to the tube and left overnight. On the next day, the absorbance of the calibration standards and samples were read through the spectrophotometer set at 600 nm wavelength. The soil organic carbon (SOC) was calculated using the formula below:

$$\%OC = \frac{mgC_{sample} - mgC_{blank}}{W, mg} \times f \times mcf \times 100$$

Where:

% OC = Organic carbon content of the soil, %

mg C_{sample} = Analyte/concentration of C in sample

mg C_{blank} = Analyte/concentration of C in blank

W = Mass of air-dry sample, mg

f = Correction factor, 1.3

mcf = Moisture correction factor

The moisture correction factor was calculated using the formula below:

Weight of water = W_2 - W_3

Weight of wet - soil = W_2 - W_1

% Moisture (wet - soil basis) = $\frac{W_2 - W_3}{W_2 - W_1} \times 100$

Moisture correction factor = $\frac{100+\ \%\ moisture}{100} \times 100$

Where:

W_1 = weight of lid and container

W_2= weight of wet soil

W_3 = weight of air-dried soil

Table 3.4: Preparation of a sucrose standard curve.

Mass of OC. (mg)	Sucrose Standard* (mL)	Distill water (mL)
0	0.00	2.00
1	0.25	1.75
2	0.50	1.50
3	0.75	1.25
4	1.00	1.00
5	1.25	0.75
6	1.50	0.50
7	1.75	0.25
8	2.00	0.00

* A stock solution of sucrose was made by mixing 0.475 g sucrose in 50 mL water.

3.4 Measurement of Vegetative Parameters

3.4.1 Leaf Area (cm^2)

Measurements of leaf area were performed on Day 30, 60 and 90 of cultivation. For each plant, three middle, mature, green leaves were selected. Middle, and mature leaf refer to a fully expanded leaf that is grew close or at the middle of whole plant stem. By multiplying the leaves width and length (Figure 3.2) to obtain the leaf area.

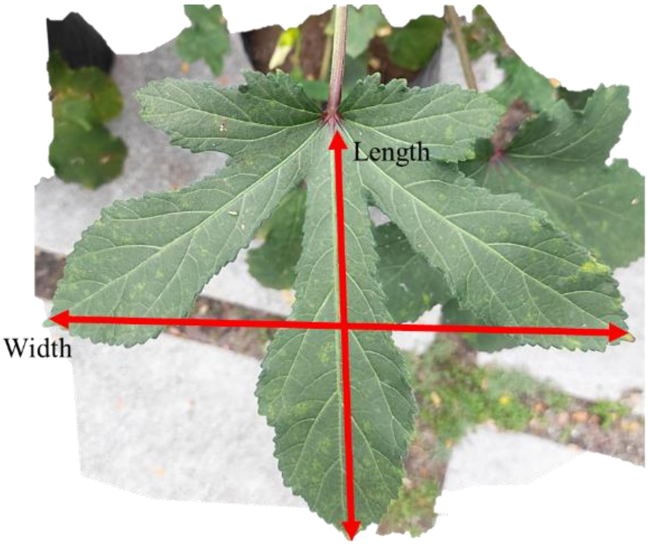

Figure 3.2: The description of leaf area measurement.

3.4.2 Plant Height (cm)

The height of each plant was measured from soil surface to the tip of main branch of plant by using a tap measure Day 90 of cultivation.

3.4.3 Stem Diameter (mm)

The stem diameter of each plant was measured at 1 cm above soil by using caliper at Day 90 of cultivation.

3.4.4 Average Dry Plant Weight and Average Dry Root Weight (g)

On Day 90 of cultivation, any fruits that are not ready to be harvested were removed. Then, the polybags were removed, and the soil was washed using tap water. Next, the shoot system part and root system part were cut and separated. All the plants and roots parts were dried in drying oven at 75˚C for 4 days. Later, the weight of plant and roots were measured by using an electronic weighing balance. The weight for dry plant parts and dry root parts were recorded.

3.5 Measurement of Yield Parameters

3.5.1 Total Fresh Pod Yield and Total Dry Pod Yield (g)

All the pods were harvested daily after 7 days of flowering. All fresh harvested pods were weighted immediately and were dried in drying oven at 75˚C for 4 days. Later, the weight of dry pod was measured and recorded by using an electronic weighing balance. Total fresh pod yield and total dry pod yield were calculated by summing the total pods collected from 5 plants of each treatment.

3.5.2 Average Fresh Pod Weight and Average Dry Pod Weight (g)

All the pods were harvested daily after 7 days of flowering. The weight of fresh harvested pods were recorded immediately. After that, the pods were dried in drying oven for 2 weeks at 75˚C. Later, the dry pods were measured again, and their weight were recorded. The average fresh pod weight and average dry pod weight were calculated using the formula below:

$$Average\ fresh\ pod\ weight\ (g) = \frac{Total\ fresh\ pod\ weight\ (g)}{Number\ of\ pods}$$

$$Average\ dry\ pod\ weight\ (g) = \frac{Total\ dry\ pod\ weight\ (g)}{Number\ of\ pods}$$

3.5.3 Days to First Flowering

Days to first flowering for each plant were calculated through counting the days from germination to the days of first flowering.

3.5.4 Number of Flowers per Plant

Number of flowers was counted daily throughout the entire cultivation period of 90 days. Average number of flowers per plant was calculated using the formula below:

$$Average\ number\ of\ flowers\ per\ plant\ = \frac{Number\ of\ flowers}{Number\ of\ plants}$$

3.6 Statistical Analysis

All data were analyzed by using one-way ANOVA with Duncan's multiple range test (DMRT) analysis and Pearson correlation coefficient through SPSS 21.0 software for comparison between treatments. The data were presented as average value ± standard deviation (SD). The significant statistical differences were set at p-value$\leq$ 0.05.

CHAPTER 4

RESULTS

4.1 Soil Chemical Analysis

4.1.1 Soil pH

Figure 4.1 shows the soil pH value of soil at Day 30 and Day 90. The soil pH of T1 increased 5.8%, T2 reduced 1%, T3 increased 2.9% and T4 increased 4.5% from Day 30 to Day 90. On Day 30, the soil pH value for T2 (6.87±0.09) and T4 (6.62±0.13) were significantly lower compared to T1 (7.18±0.08) and T3 (7.33±0.07), while on Day 90, the soil pH value for T2 (6.8±0.10) and T4 (6.92±0.11) were also significantly lower compared to T1 (7.60±0.07) and T2 (7.54±0.10), showing that both T2 and T4 reduced soil pH (Figure 4.1).

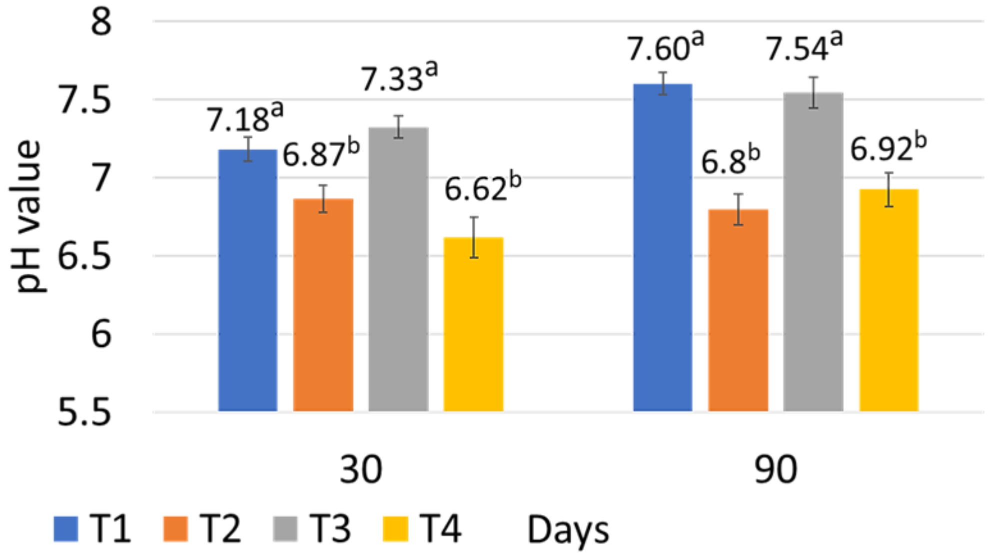

Figure 4.1: The soil pH value at Day 30 and Day 90. T1=Control, T2=NPK fertilizer, T3=Fermented fruit peel waste, T4=Oil palm waste compost (Baba). The average values with different superscript letters (a-b) represented as significant difference ($p \leq 0.05$, n=5). The blocking effect is not significant ($p \leq 0.05$) for soil pH as listed in Appendix C Figure 1.

4.1.2 Soil Electrical Conductivity (EC)

Figure 4.2 shows the EC (µs/cm) of soil at Day 30 and Day 90.The soil EC of T1 decreased 8.8%, T2 reduced 9%, T3 increased 3.8% and T4 decreased 89% from Day 30 to Day 90. On Day 30, the soil EC for T2 (169.3±96.53 µs/cm) and T4 (252.7±80.13 µs/cm) were significantly lower compared to T1 (86.3±5.77 µs/cm) and T3 (71.30±9.45 µs/cm). On Day 90, the soil EC for T2 (155.30±18.04 µs/cm) and T4 (133.30±21.94 µs/cm) were also significantly lower compared to T1 (79.3±10.26 µs/cm) and T3 (74±22.54 µs/cm), showing that the T2 and T4 increased the soil EC (Figure 4.2).

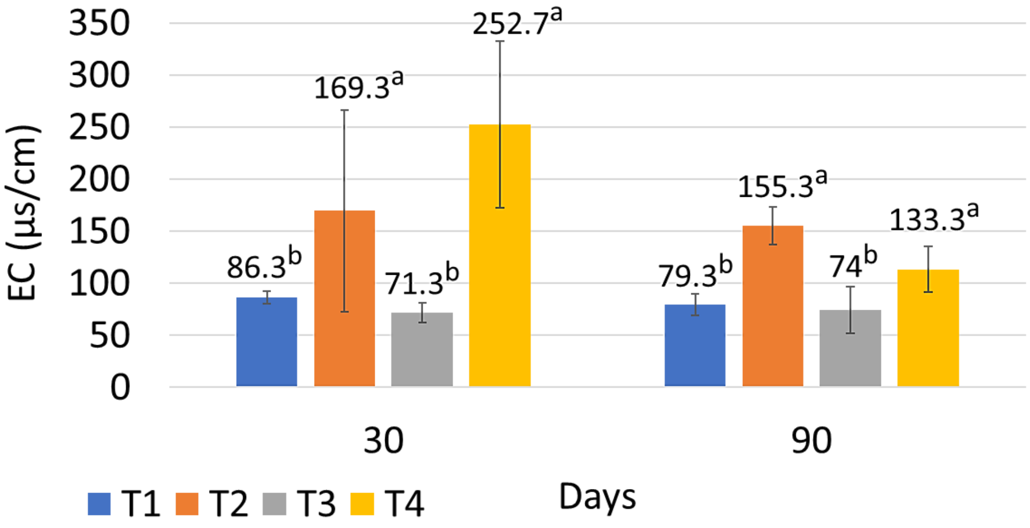

Figure 4.2: The EC (µs/cm) of soil at Day 30 and Day 90. T1=Control, T2=NPK fertilizer, T3=Fermented fruit peel waste, T4=Oil palm waste compost (Baba). Average values with different superscript letters (a-b) represented as significant difference ($p \leq 0.05$, n=5). The blocking effect is not significant ($p \leq 0.05$) for soil EC as listed in Appendix C Figure 2.

4.1.3 Soil Organic Carbon Concentration (SOC)

Figure 4.3 shows the SOC (%) of soil at Day 30 and Day 90 while Table 4.1 shows the percentage of increment or reduction for SOC from Day 30 and 90 for each treatment. On Day 30, the SOC for T1, T2, T3 and T4 were

1.14±0.31%, 1.14±0.47%, 1.14±0.17% and 0.99±0.13%. On Day 90, the SOC for T1, T2, T3 and T4 were 0.86±0.18%, 1.02±0.13%, 0.99±0.19%, and 1.04±0.16%. From the result, the SOC among different treatments did not show any significant difference on Day 30 and 90. However, T1,T2, and T3 recorded a numerical reduction of SOC from Day 30 to 90 and T4 had an increasing SOC in the same period (Table 4.1 and Figure 4.3).

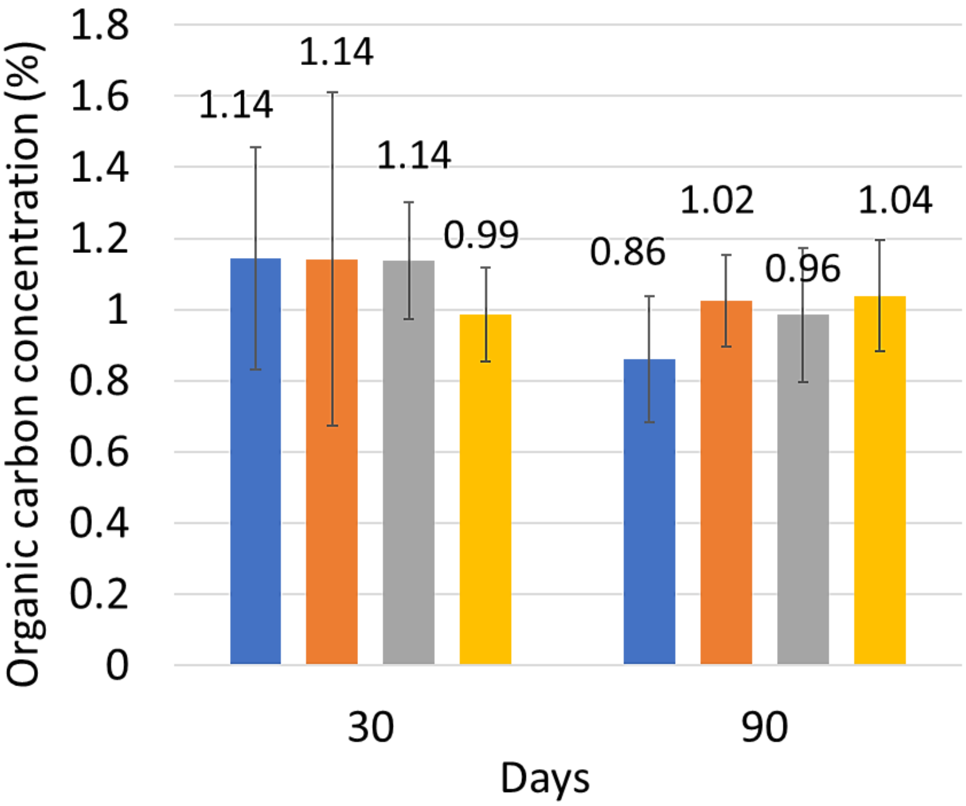

Figure 4.3: The SOC (%) of soil at Day 30 and Day 90. T1=Control, T2=NPK fertilizer, T3=Fermented fruit peel waste, T4=Oil palm waste compost (Baba). (n=5). The blocking effect is not significant ($p \leq 0.05$) for SOC as listed in Appendix C Figure 3.

Table 4.1: The percentage of increment or reduction for SOC from Day 30 and 90 for each treatment.

Treatments	Percentage of increment or reduction of SOC from 30-days to 90-days
1	-24.8%
2	-10.2%
3	-13.4%
4	+5.3%

4.2 Vegetative Parameters

4.2.1 Average Leaf Area (cm²)

Figure 4.4 shows the average leaf area of okra from Day 30, 60 and 90 of cultivation. On Day 90, the T4 (615.51±43.26 cm²) recorded significantly higher average leaf area compared to T2 (193.90±44.50 cm²), T1 (140.22±29.53 cm²), and T3 (140.81±30.15 cm²). On Day 30, 60, and 90, the T4 also showed significantly higher leaf area compared to T2, T3 and T1 (Figure 4.4).

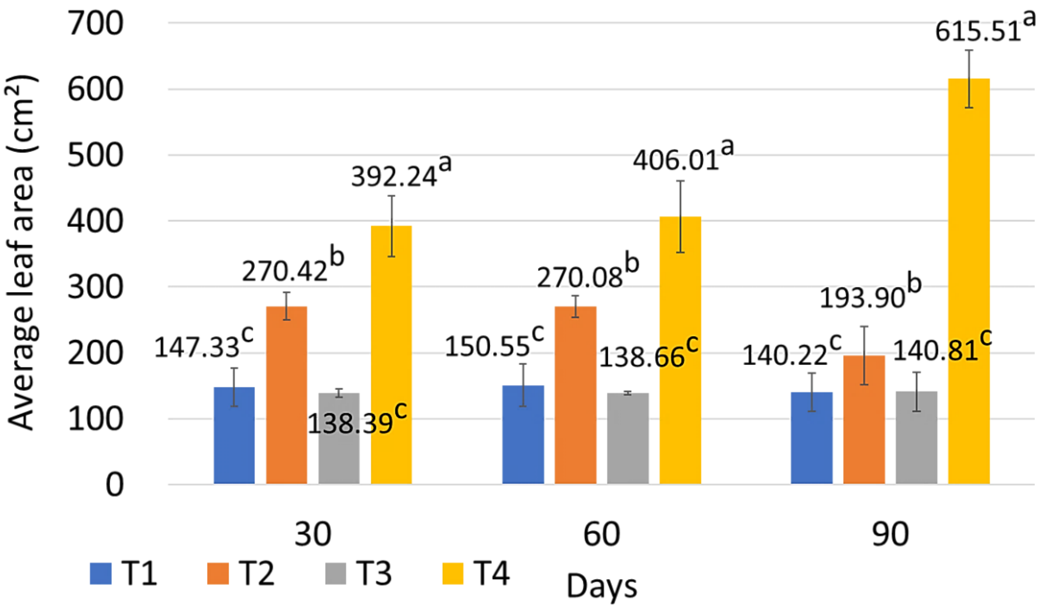

Figure 4.4: The average leaf area of okra plants from Day 30, 60 and 90 of cultivation. T1=Control, T2=NPK fertilizer, T3=Fermented fruit peel waste, T4=Oil palm waste compost (Baba). Average values with different superscript letters (a-c) represented as significant difference ($p \leq 0.05$, n=5). The blocking effect is not significant ($p \leq 0.05$) for average leaf area of okra plants as listed in Appendix C Figure 4.

4.2.2 Average Plant Height (cm)

Figure 4.5 shows the average height of okra plants at Day 90. The T4 (124.77±21.67 cm) recorded a significantly higher average okra plant height compared to T2 (83.21±10.92 cm), T1 (60.87±8.10 cm), and T3 (62.96±10.07 cm) after 90 days of cultivation.

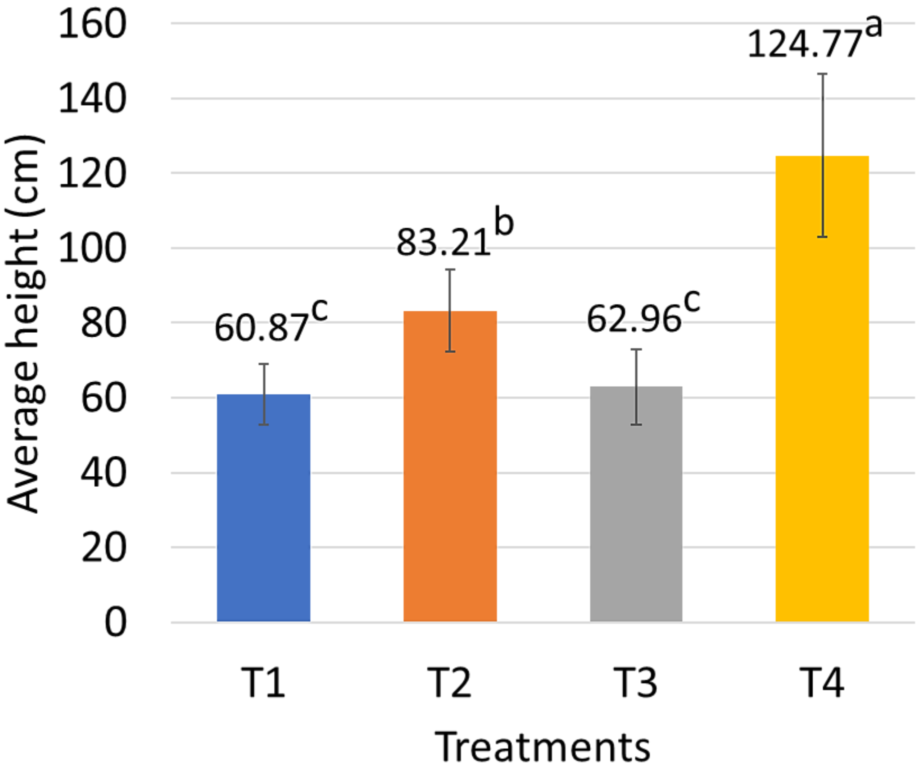

Figure 4.5: The average height of okra plants at Day 90. T1=Control, T2=NPK fertilizer, T3=Fermented fruit peel waste, T4=Oil palm waste compost (Baba). Average values with different superscript letters (a-c) represented as significant difference ($p \leq 0.05$, n=15). The blocking effect is not significant ($p \leq 0.05$) for average height of okra plants as listed in Appendix C Figure 5.

4.2.3 Average Stem Diameter (mm)

Figure 4.6 shows the average stem diameter of okra plants at Day 90. As shown in Figure 4.6, the T4 (17.02±2.28 mm) had significant higher average okra plants stem diameter compared to T2 (12.28±1.44 mm), T1 (7.85±0.85 mm), and T3 (8.05±1.07 mm) after 90 days of cultivation.

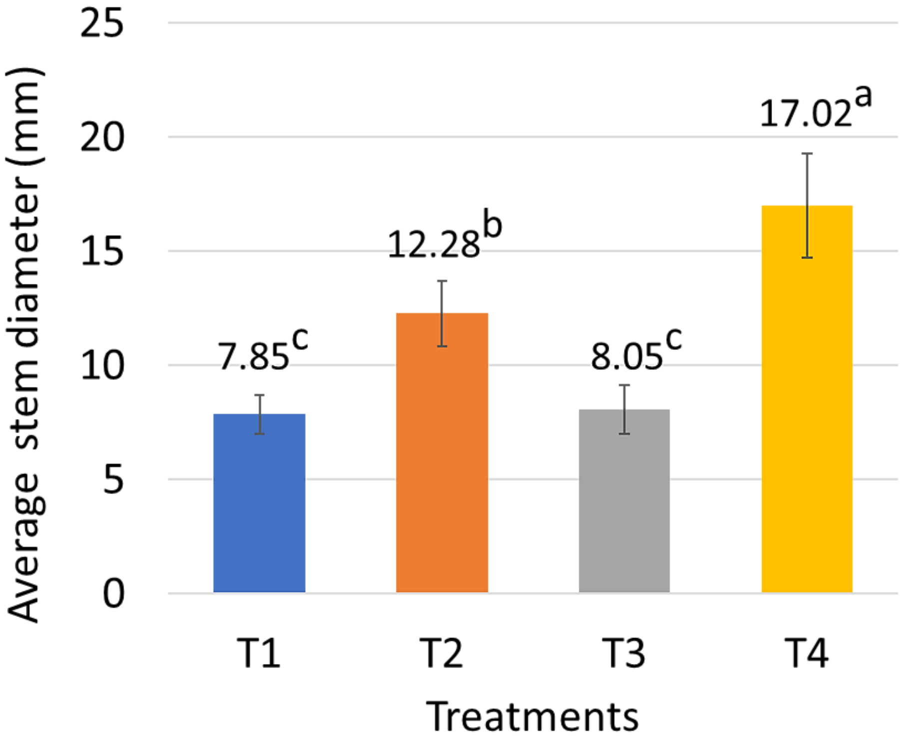

Figure 4.6: The average stem diameter of okra plants at Day 90. T1=Control, T2=NPK fertilizer, T3=Fermented fruit peel waste, T4=Oil palm waste compost (Baba). Average values with different superscript letters (a-c) represented as significant difference ($p \leq 0.05$, n=15). The blocking effect is not significant ($p \leq 0.05$) for average stem diameter of okra plants as listed in Appendix C Figure 5.

4.2.4 Average dry plant weight (g)

Figure 4.7 shows the average dry plant weight of okra plants at Day 90. The T4 (45.361±17.40 g) recorded a significantly higher average dry plant weight compared to T2 (20.21±5.98 g), T1 (7.34±2.60 g), and T3 (7.55±2.82 g) after 90 days of cultivation.

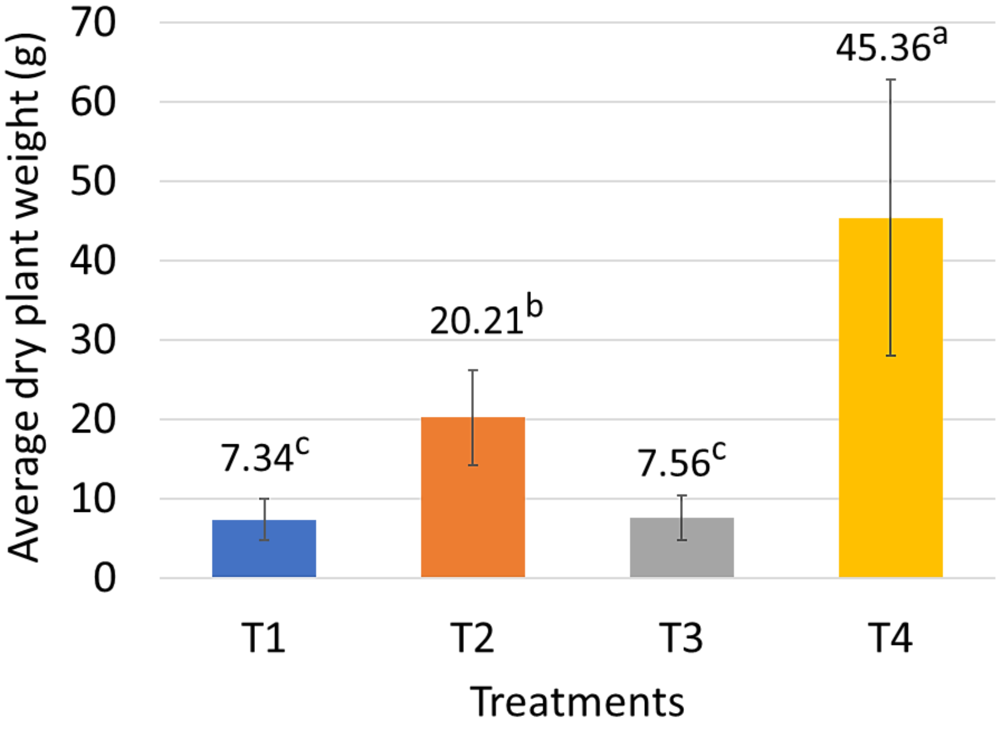

Figure 4.7: The average dry plant weight of okra plants at Day 90. T1=Control, T2=NPK fertilizer, T3=Fermented fruit peel waste, T4=Oil palm waste compost (Baba). Average with different superscript letters (a-c) represented as significant difference ($p \leq 0.05$, n=15). The blocking effect is not significant ($p \leq 0.05$) for average dry plant weight of okra plants as listed in Appendix C Figure 5.

4.2.5 Average dry root weight (g)

Figure 4.8 shows the average dry root weight of okra plants at Day 90. The T4 (19.81±9.76 g) had significant higher average dry root weight compared to T2 (9.17±2.63 g), T1 (2.51±1.11 g), and T3 (2.57±1.43 g) after 90 days of cultivation.

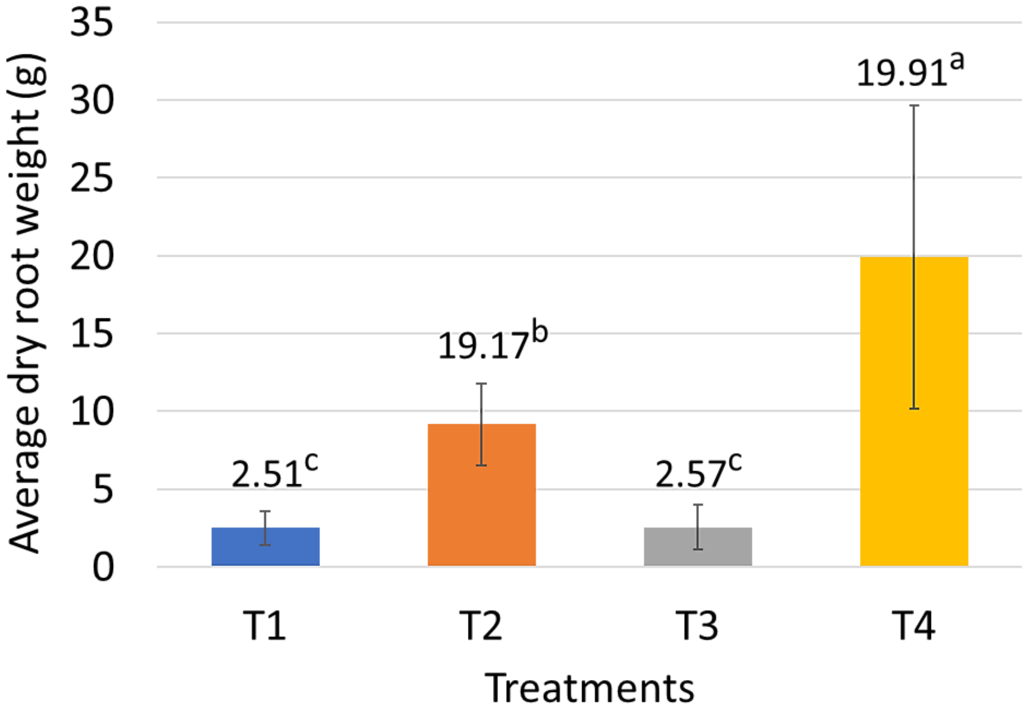

Figure 4.8: The average dry root weight of okra plants at Day 90. T1=Control, T2=NPK fertilizer, T3=Fermented fruit peel waste, T4=Oil palm waste compost (Baba). Average value with different superscript letters (a-c) represented as significant difference ($p \leq 0.05$, n=15). The blocking effect is significant ($p \leq 0.05$) for average dry root weight of okra plants as listed in Appendix C Figure 5.

4.2.6 Growth of Okra

The okra plants grew well without serious pest damage, plant diseases, root diseases and other damage. From 30-days of cultivation to 90-days of cultivation, the plants were observed to grow taller and larger. However, some plants have yellow leaves may be due to natural defoliation on 90-days of cultivation (see Appendix B).

4.3 Yield parameter

4.3.1 Total Fresh Pod Yield and Total Dry Pod Yield (g)

Figure 4.9 shows the (a) total fresh pod yield and (b) total dry pod yield of okra plants at Day 90. For total fresh pod yield, the T4 (1328.64±129.17 g) had significant higher total dry pod yield compared to T2 (560.12±111.32 g), T1 (165.16±42.28 g), and T3 (134.02±20.78 g). For total dry pod yield, the T4 (125.24±21.35 g) had significant higher total dry pod yield compared to T2 (43.83±4.16 g), T1 (15.57±4.83 g), and T3 (12.21±1.55 g).

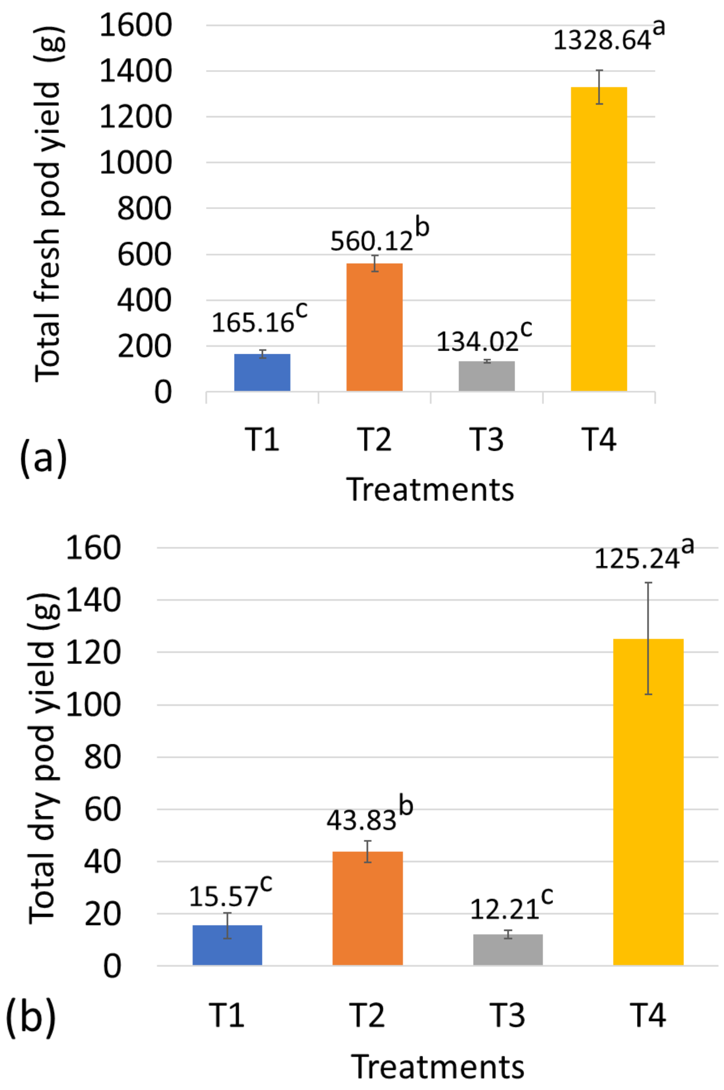

Figure 4.9: The (a) total fresh pod yield and (b) total dry pod yield of okra plants at Day 90. T1=Control, T2=NPK fertilizer, T3=Fermented fruit peel waste, T4=Oil palm waste compost (Baba). Average values with different superscript letters (a-c) represented as significant difference ($p\leq0.05$). The blocking effect is not significant ($p\leq0.05$) for total fresh pod yield of okra plants, however the total dry pod yield of okra plants had a significant ($p\leq0.05$) blocking effect as listed in Appendix C Figure 6 and 7.

4.3.2 Average Fresh Pod Weight and Average Dry Pod Weight (g)

Figure 4.10 shows the (a) average fresh pod weight and (b) average dry pod weight of okra plants at Day 90. For average fresh pod weight, the T4 (27.25±3.16 g) had significant higher total dry pod yield compared to T2

(21.70±3.11 g), T1 (11.76±2.96 g), and T3 (14.45±3.89 g). For average dry pod weight, the T4 (2.69±0.31 g) had significant higher total dry pod yield compared to T2 (1.87±0.28 g), T1 (1.07±0.27 g), and T3 (1.37±0.49 g).

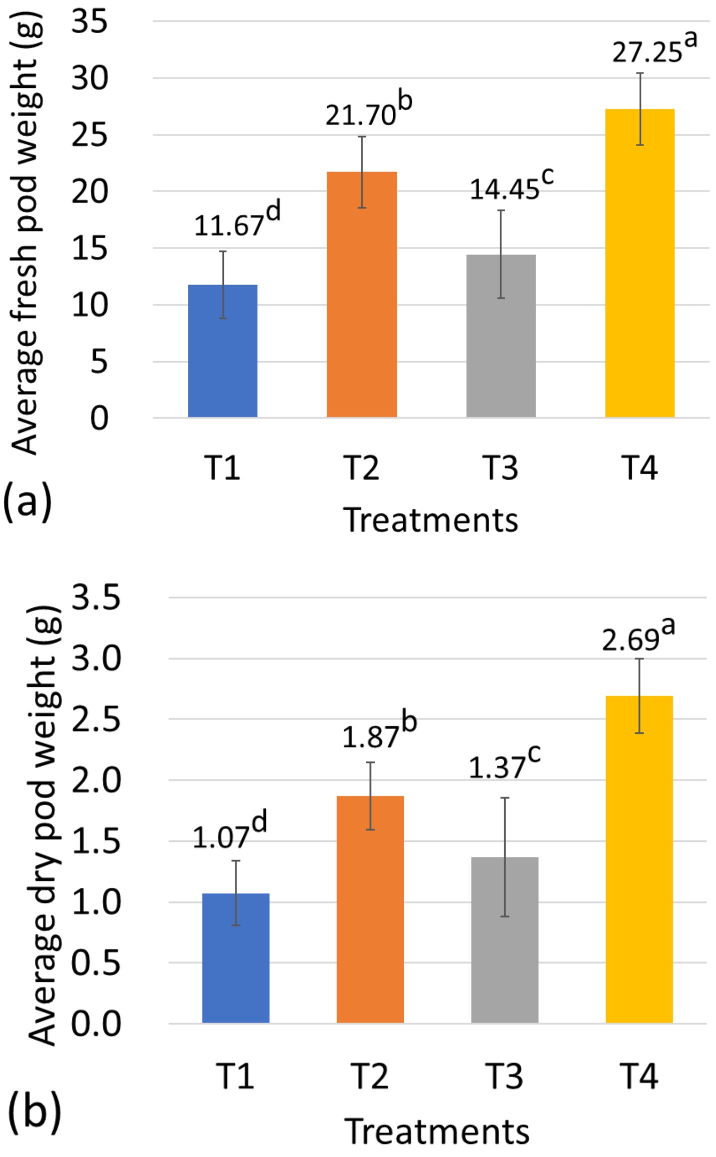

Figure 4.10: The (a) average fresh pod weight and (b) average dry pod weight of okra plants at Day 90. T1=Control, T2=NPK fertilizer, T3=Fermented fruit peel waste, T4=Oil palm waste compost (Baba). Average values with different superscript letters (a-d) represented as significant difference ($p \leq 0.05$). The blocking effect is not significant ($p \leq 0.05$) for average fresh pod weight and average dry pod weight of okra as listed in Appendix C Figure 8 and 9.

4.3.3 Days to First Flowering

Figure 4.11 shows the days to first flowering of okra plants. Days to first flowering for T1 and T3 is 40 days while T2 and T4 is 37 days. T4 had significantly lower days to first flowering compared to T1 and T3. Meanwhile, there are no significant difference between T1, T2 and T3.

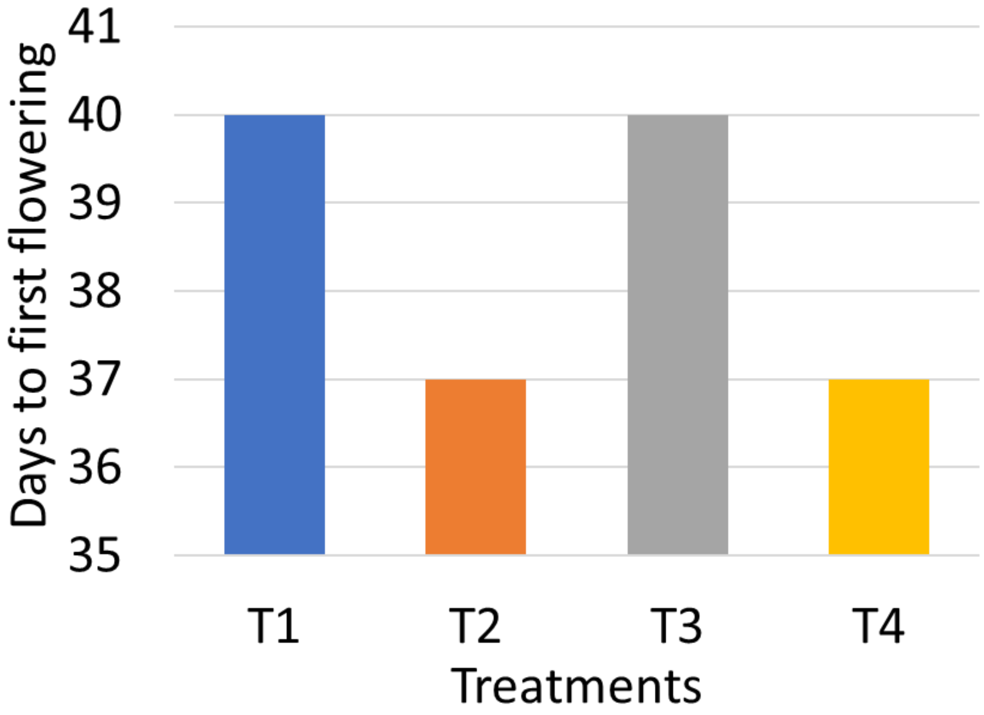

Figure 4.11: The days to first flowering of okra plants. T1=Control, T2=NPK fertilizer, T3=Fermented fruit peel waste, T4=Oil palm waste compost (Baba). Average values with different superscript letters (a-c) represented as significant difference ($p \leq 0.05$). The blocking effect is not significant ($p \leqslant 0.05$) for days to first flowering of okra plants as listed in Appendix C Figure 10.

4.3.4 Average Number of Flowers per Plant

Figure 4.12 shows the average number of flowers per plant of okra plants at Day 90. The T4 (11.67±2.79 g) had significant higher total dry pod yield compared to T2 (6.47±2.03 g), T1 (4±2 g), and T3 (3.57±1.95 g).

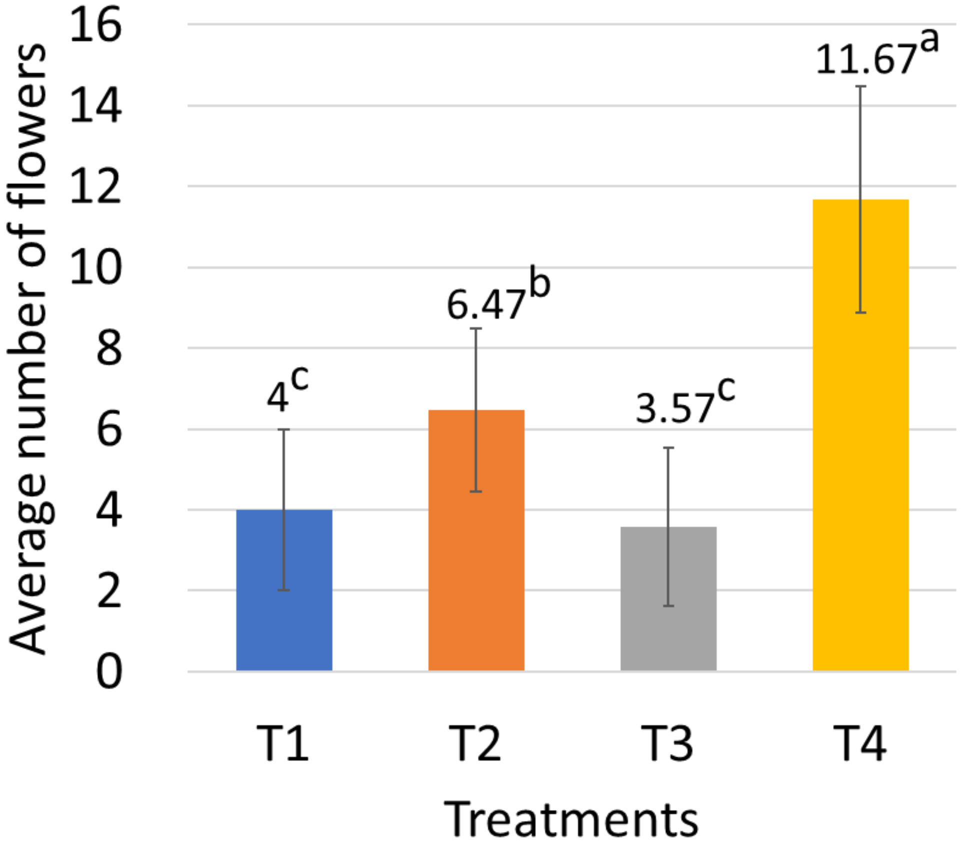

Figure 4.12: The average number of flowers of okra plants at Day 90. T1=Control, T2=NPK fertilizer, T3=Fermented fruit peel waste, T4=Oil palm waste compost (Baba). Average values with different superscript letters (a-c) represented as significant difference ($p \leq 0.05$, n=5). The blocking effect is significant ($p \leqslant 0.05$) for average number of flowers per plant of okra plants as listed in Appendix C Figure 11.

4.4 Summary of Vegetative and Yield Parameters

The relative performance of the treatments used in the present study on the soil, vegetative, yield parameters are analyzed and summarized respectively in Table 4.2, 4.3 and 4.4.

Table 4.2: The summary of the soil parameters.

Soil parameters	Results
Soil pH value	T3 & T1 > T4 & T3
Soil EC	T4 & T3 > T3 & T1
Soil SOC	No significant difference (p≤0.05) among days T1, T2, T3 – Decreasing from Day 60 to Day 90 of cultivation T4 – Increasing from 60 to 90-days of cultivation

Greater-than sign “ > ” indicates significant difference (p≤0.05)
Esperluette “ & ” indicates no significant difference (p≤0.05). The treatment with larger value is listed former, smaller value is listed latter.

Table 4.3: The summary of the vegetative parameters.

Vegetative parameters	Results
Average leaf area	T4>T2>T1&T3
Average height	T4>T2>T1&T3
Average stem diameter	T4>T2>T1&T3
Average dry plant weight	T4>T2>T1&T3
Average dry root weight	T4>T2>T1&T3

Greater-than sign “ > ” indicates significant difference (p≤0.05)
Esperluette “ & ” indicates no significant difference (p≤0.05). The treatment with larger value is listed former, smaller value is listed latter.

Table 4.4: The summary of the yield parameters.

Yield parameters	Results
Total fresh pod yield	T4>T2>T1&T3
Total dry pod yield	T4>T2>T1&T3
Average fresh pod weight	T4>T2>T3>T1
Average dry pod weight	T4>T2>T3>T1
Number of flowers per plant	T4>T2>T1&T3
Days to first flowering	T4<T1&T3, Meanwhile, there are no significant different between T1, T2 and T3.

Greater-than sign “ > ” indicates significant difference ($p \leqslant 0.05$)
Esperluette “ & ” indicates no significant difference ($p \leqslant 0.05$). The treatment with larger value is listed former, smaller value is listed latter.

4.5 Calculations of Cost / Cost Estimation

Table 4.5 shows the calculation of estimated treatments cost. Total application of T2 and T3 is 6 times, while the T4 is 2 times. Each treatment had 15 plants, 7 kg soil in each polybag. The estimated treatment cost was calculated as shown in below:

Table 4.5: Calculation of estimated treatments cost.

Treat-ments	**Doses**	**Materials and estimated cost**	**Estimated costs**
T1	-	-	RM 0.00
T2	0.1 g/kg soil (Jallow, Sey and Manneh, 2021)	1 kg NPK fertilizer is RM 7.5 Total NPK fertilizer used : 0.7 g*15*6 = 63 g	0.063 kg*7.5 = RM 0.47
T3	(diluted) 50 mL/kg soil	Price for brown sugar is RM 3.5 per 1 kg Total diluted FFPW: 50 mL*7*15*6= 31500 mL Total undiluted FFPW: 31500 mL/100 = 315 mL Total brown sugar used: 315 mL/14 = 22.5 g	0.0225 kg*3.5=RM 0.08
T4	350 g/plant each time (5%) (Pérez et al., 2021)	Weight of per compost package ≈ 3 kg or 7 L[a] Price of compost per bag = RM 12 Total compost used: 350 g *15*2 = 10.5 kg Number of bag compost used: 10.5/3 = 3.5 ≈4 bags	4*RM 12 = RM 48.00

T1=Control, T2=NPK fertilizer, T3= FFPW, T4 = Oil palm waste compost (Baba)
[a] Improper storage of compost causing the weight to be fluctuated.
Note: The water, labour, weeding, pest control cost is not calculated in this study.

Table 4.6 shows the economic profit per treatments. All the harvested fresh okra pods per treatment are assumed to be sold, either with the Kuala Lumpur local price RM 5.46/kg fresh pod (Tridge, 2021) or Malaysia organic okra price RM 18/kg fresh pod (33 Dusun Segar Trading, 2022). T4 incurred the highest fertilizers costs compared to T3, followed by T2 and T1. Then, the T2 has the highest profit compared to T1, followed by T3 and T4. However, if the okra is sold as organic okra, T4 has the highest profit, followed by T2, T1 and T3.

Table 4.6: The economic profit per treatments.

Treatments	Estimated costs	Sale value per treatment[a]	Profits[b]
T1	RM 0.00	0.495 kg * RM 5.46 = RM 2.70	RM 2.70
T2	RM 0.47	1.680 kg * RM 5.46 = RM 9.20	RM 8.73
T3	RM 0.08	0.402 kg * RM 5.46 = RM 2.20	RM 2.20
T4	RM 48.00	3.986 kg * RM 5.46 = RM 21.80	-RM 26.20
		3.986 kg * RM 18 = RM 71.75	RM 23.75

T1=control, T2=NPK fertilizer, T3= FFPW, T4 = Oil palm waste compost (Baba)

[a] Formula of sale value per treatment = Total fresh pod yield per treatment*price.

[b] Formula of profit = Sale value per treatment- Estimated treatments costs.

CHAPTER 5

DISCUSSION

5.1 Soil Chemical Analysis

5.1.1 Soil pH

Soil pH is a measure for concentration of H^+ ions and OH^- ions present in the soil, the degree of soil alkalinity or acidity (Weil and Brady, 2017; Shoily, 2021). Soil with 1:1 ratio of H^+ ions and OH^- ions will result around pH 7. It is better to have a neutral soil condition, for facilitating the absorption of ions. If the soil has more H^+ ions, then the soil will show a lower pH value below 7, which is an acidified soil condition (Chesworth, 2008; Weil and Brady, 2017).

From Figure 4.1, the soil pH of T2 and T4 were significantly lower compared to T1 and T3, showing that the treatment had a decreasing effect on the soil The acidification of soil pH by T2 soil could be due to nitrification of soil microbes. Plant generally prefers nitrate ion compared to ammonia ion even through both ions are adsorbable to the plant (Weil and Brady, 2017). There are majority of two type of chemical fertilizers, which are ammonia-based and nitrate-based fertilizer. However, in this study, we were not able to analyze the type of fertilizers due to insufficient time. There are also many different components that used to make chemical fertilizers included ammonium nitrate (AN), urea, urea ammonium nitrate (UAN), and ammonium sulfate (Caicedo, 2000; Yara International, 2015). For example, ammonia nitrate is a nitrate-based NPK fertilizer. It will product 50% ammonia ions and 50% nitrate ions. The 50% ammonia ions will be converted to nitrate ions and two H^+ ions will be release (Figure 5.1) during the nitrification process by soil microbes (Yara International, 2015; Weil and Brady, 2017). Besides that, if ammonium-based NPK fertilizer is used as the fertilizers, the ammonium sulfate will be oxidized and produced nitric acid and sulfuric acid, which can acidify the soil (Figure 5.2) (Weil and Brady, 2017).

$$NH_4^+ + 2O_2 \rightleftharpoons H_2O + H^+ + \underbrace{H^+ + NO_3^-}_{\substack{\text{Dissociated}\\ \text{nitric acid}}}$$

Figure 5.1: Nitrification of ammonia ions (Weil and Brady, 2017).

$$(NH_4)_2SO_4 + 4O_2 \rightleftharpoons \underset{\text{Nitric acid}}{2HNO_3} + \underset{\text{Sulfuric acid}}{H_2SO_4} + 2H_2O$$

Figure 5.2: Oxidization of ammonium-based NPK fertilizer (Weil and Brady, 2017).

The source of H^+ ions may come from the decomposition of organic matter by soil microbes (Weil and Brady, 2017). In T4, it is quite likely that the decomposition of organic matter (oil palm waste compost) by soil microbes generates organic acid such as fulvic acid, citric acid and humic acid. While the organic matter also can be decomposed into stronger acid form like carboxylic, phenolic acid groups in humus. Meanwhile, the organic matter will also facilitate the loss of cations (Ca and Mg) through leaching. The loss of these cations also contributed to soil acidity (McMillan and Small, 2016).

As the soil pH increase, the availability of ions such as Al, Mn, Cu, Fe, Cu, Zn and Mn is also affected by soil pH. The optimum mineral soil pH for most of the plant growth is between 5.5 to 6.5. For okra, its optimum growth occurs at soil pH of 5.5 to 7 (Old Farmer‘s Almanac, 2019; Masabni, n.d). The soil pH determines the nutrient uptake of plants from the soil. When soil pH decreases below 5.5, the availability of P and Mg decrease, while the availability of Al, Mn and Cu increase. Then, when the soil pH increases above 6.5, availability of Fe, Cu, Zn and Mn decreases (McMillan and Small, 2016). Fe, Cu, Zn and Mn are the four essential micronutrients for plant growth (Jones, 2012). The importance of Fe, Cu, Zn and Mn were showed in Table 5.1. From the Figure 4.1, the T1 and T3 had a pH value higher than 7, so we infer it may face difficulties in intaking of Fe, Cu, Zn and Mn, however, we did not observe nutrient deficiency symptoms of Fe, Cu, Zn and Mn on the plants.

Table 5.1: The functions and its available forms of soil micronutrients (Jones, 2012).

Micronutrients	Functions	Available forms
Cu	• Component of chloroplast protein plastocyanin in the photosynthesis process • Constituent of enzymes in ascorbic acid oxidase and cytochrome oxidase	• Fulvic acids and humic acids
Fe	• Component of enzyme in cytochrome oxidase, protein ferredoxin, energy production	• Ferric and ferrous ions
Mn	• Essential in photosystem II • Act as bridge for phosphotransferases, activates dehydrogenase, and nitrogen assimilation	• Manganese ion
Zn	• Component of peptidase, proteinase, and dehydrogenase • Carbonic anhydrase only activated by Zn • Promotes seed maturation and production	• Zinc ions

Meanwhile, there are several other studies that was in agreement with the findings of this study that the NPK and organic fertilizers can improve soil fertility, plant growth and yield. The study of Kota et al., (2022) revealed that the soil applied with organic fertilizers like rabbit manure, poultry manure, and cow dung decreased the soil pH compared to control (no fertilizer) even there are no significant difference. Meanwhile, there are significant difference between NPK fertilizer and control, the NPK fertilizer had a significantly lower soil pH than control (no NPK fertilizer). However, the study of Li et al. (2022), showed a significant difference on decreasing of soil pH with treatment of 18 t/ha of cattle manure compared to treatment with 0.6 tons of NPK fertilizer. The researchers also found that when the soil pH decreased, maize height, stem diameter, fresh root weight and fresh shoot weight increased. However, there is no articles trying to relate soil pH to okra growth performance

5.1.2 Soil Electrical Conductivity (EC)

EC is an indication of soil salinity or salt content. However, it does not indicate the concentration of a particular ions or compounds in soil solution (USDA, 2014). The higher value of EC, indicating the more mobile ions contained in the soil. If the soil has very low EC, meaning that the free ion is low in soil solution. The ions or nutrients in the soil solutions are the factors affecting plant growth and yield. The free ions in the solution can be uptake by the plant root for plant development (Weil and Brady, 2017). For example, the soil EC have a positive correlation with the soil N content. This is due to the addition of potential nutrients level that increases the amount of ionized nutrients (Suud, Syuaib and Astika, 2016). When they are many ionized N available for the plant, the plant will grow higher and have higher yield. A low nutrients level will result the plant to be slow in growth and produce lesser yield (Lu et al., 2022). Therefore, an optimal ECcan give a better plant growth and yield (Bleam, 2017 ; Putranta et al., 2019). For example, in the study of Lu et al., (2022), an optimal nutrient solution with 4.5 ms/cm EC had a higher the chlorophyll content, photosynthetic rate, and transpiration rate of cherry tomato plants, that produced more food for the plant to grow compared to 3 ms/cm EC.

From the Figure 4.2, the soil EC of T2 and T4 were significantly higher than T1 and T3, showing there was an increasing effect on the soil EC for Day 30 and 90. The result of EC showed that NPK fertilizer and compost can contribute free soluble mobile ions to the soil solution. Because of the presence of free ions in the soil solution, it can transfer charge from one electron to another electrons, showing numeric reading on the EC meter. High soil EC value indicates that free ions are abundant which facilitates plant uptake leading to increase plant growth and yield (USDA, 2014; Jamal et al., 2015; Inamuddin et al., 2021).

There are similar studies that support the findings of this study. For soil fertility, the study of Usevičiūtė, Baltrėnaitė-Gedienė and Feizienė, (2021) revealed that the NPK fertilizer can improve the EC and spearmint growth compared to control. Research from Koulali, et al., (2014) also showed that turkey manure compost improved the soil EC from 350 to 600 μS/cm. The EFB-based compost also results an improvement of EC from 15 μS/cm to average

154.7µS/cm**.** From these studies, it proven that NPK fertilizer, turkey manure compost, and EFB-based compost can increase EC in soil.

Other than that, in study of Aji et al., (2021), the food waste compost improved the soil EC from 0.01 mS/cm to 1.3 mS/cm as the compost input increased from 0% to 40%. It also increased plant height, leaf area and number of leaves of dwarf crape jasmine. On the crop performance, the Cymbidium ‘Sleeping Nymph’ applied with NPK 20:20:20 with 1.5 mS/cm significantly had higher plant height and leaves length compared to NPK 20:20:20 with 1 mS/cm (Naik et al., 2013), showing the increasing the EC in soil will give higher plant height and leaf length. However, there is no articles trying to relate soil EC to okra growth performance

5.1.3 Soil Organic Carbon Concentration (SOC)

Soil organic carbon (SOC) is the carbon component of organic matters (Edwards, 2019). A fresh organic residue decomposes into active soil organic matter SOM and slow SOM (McCauley, Jones and Jacobsen, 2009). The active SOM from dry organic residue refers as detritus. Detritus is a food source for soil microbes and it is also responsible for water and nutrients retention as well as stabilization of soil aggregates (Kumar et al., 2020). The soil microbes play roles for stabilization of soil aggregates. The organic matter is the food of the soil fauna (nematodes, protozoa, mites, springtails), flora (bacteria, fungi). It can increase the population of soil microbes, which supported by study of Chauhan et al. (2011), finding that the soil with organic input had higher microbial population. xxx

The slow SOM from fresh residue refers as humus (Kumar et al., 2020). The slow decomposition of SOM is a long-term nutrients source of plant. The humus act as a chelate to bind with metal ions in soil (Fe, Zn, Mn, and Cu), increasing the ions availability for plant uptake through preventing the formation of insoluble compounds. In the soil solution, when the humus and cations are inn the vicinity of the root hair, the humus will release the ions and root hair will take up the ions by exchanging them with H^+ ions. Other cations will bind to the humus to replace the exchanged ions on humus (Weil and Brady, 2017).

When the soil fauna or soil microbes moving through the soil searching for food (detritus and humus), that actions increase the amount of micropores and macropores (McCauley, Jones and Jacobsen, 2009). The spaces between soil particles also hold soil solution and air. The micropores and macropores are the main classes of the soil pores. Macropores are important for water infiltration and air exchange whereas the micropores act to retain the water that cannot be used plant for the soil microbes (Weil and Brady, 2017). The soil pores also prevent elasticity and deformation in soil with high content of clay. The increasing of the area of soil particles allows the movement of air and water, facilitating biochemistry reaction of soil such as microbial carbon-hydrogen debonding in cycling of nutrients (Weil and Brady, 2017; Haider and Schäffer, 2009), microbial phytoremediation of heavy metal in soil (González-Henao and Ghneim-Herrera, 2021) and C-C debonding of lignolytic enzymes in decomposition of lignin (Haider and Schäffer, 2009).

According to Table 4.1, T1, T2 and T3 have a decreased SOC from days 30 to 90, however the T4 shown an increasing organic carbon concentration to around 5% from Days 30 to Days 90, even though there was no significant difference among the treatments on Day 30 and 90. Since T1 and T2 offer no organic matter input at all, so it results a decreasing of SOC from days 30 to days 90 as they are depleted naturally.

For the T3, there are three possible explanations on the low SOC reported in this study. Firstly, FFPW has been reported to have lower carbon content (2.62%) than EFB-based compost (7.2%) and poultry manure (25%) despite being a form of organic fertilizer (Vimala and Sukra, 2010, Vakili et al., 2014; Rasit, Lim and Ghani, 2019). Secondly, the dilution of FFPW with water at ratio of 1:100 before being applied to the soil. It reduced the carbon content of the treatment. Thirdly, the sandy and porous nature of ex-tin mining soil exhibited poor water and nutrients holding capacity, leading to nutrients leaching shortly after FFPW application, which has happened on T2.

On the other hand, T4 showed increasing of organic carbon concentration because the T4 is an oil palm waste-based compost made by oil palm meal and other fibrous materials. According to analysis of Vimala and Sukra, (2010), and Vakili et al., (2014) for the EFB-based compost, the EFB-based compost (7.2%) generally has a higher organic carbon content compared to FFPW (2.62%) (Rasit, Lim and Ghani, 2019). Meanwhile, it can act as a topsoil helping in reserving nutrient and water resulting in less nutrients leaching happened on T4 soil. Therefore, the organic carbon concentration could have been maintained.

To support the result that T4 improved SOC, there are similar results from other researchers. In the experiment of Adekiya et al., (2020), the poultry manure has higher organic carbon content than green manure, NPK fertilizer and control. The okra growth on poultry manure has a better plant growth and yield compared to green manure, NPK fertilizer and control. The application of organic fertilizer can increase the soil organic carbon to 23-33% and 7-12% over the control and NPK fertilizer (Hwang et al., 2019). The tree leaves compost had significantly improved organic carbon content than NPK fertilizer on the wheat growth and yield (Moharana et al., 2020).

Wolf and Snyder, (2003) claimed that the C/N ratio of organic matter will affect the decomposition rate and mineralization of nitrogen, because nitrogen content determines the growth of soil microbes that mineralize organic carbon. There was no doubt that the FFPW (0.68%), EFB-based compost (0.6%) and poultry manure (1.73-3.04%) have different nitrogen content by referring the analysis of Vimala and Sukra, (2010), and Vakili et al., (2014). Thus, NPK nutrients content and C/N ratio in the NPK fertilizer, FFPW, and oil palm waste compost (Baba) used in this study should be determined.

5.1.4 Summary of Soil Analysis

Overall, the oil palm waste compost (Baba) had proven that it can reduce soil pH value, increase EC, and maintain SOC compared to FFPW, NPK fertilizer, and control with no fertilization. Oil palm waste compost (Baba) is the best fertilizer to amend the ex-tin mining in this study, followed by NPK fertilizer and FFPW.

5.2. Vegetative Parameters

5.2.1. Average Leaf Area (cm^2)

The average leaf area showed a result of T4 higher than T2, followed by T3 and T1. The soil fertility determines how well the plant grow. The T4 greatly improved soil fertility, followed by T2 in term of the soil pH and EC. The T3 and T1 soil fertility did not improve so much compared to T4 and T3, hence T3 and T1 showed smaller leaf area. The study of Dada and Adejumo (2015) reported that the compost made by weed and poultry manure can improve leaf area and plant growth even under varied dose and light intensity. The application of poultry manures also resulted in the highest leaf area compared to NPK fertilizer and control (Khandaker, Hafiza and Ralmi, 2017). In summary, the compost application in T4 resulted higher average leaf area compared to NPK fertilizer (T2) and control (T1).

Increased leaf area may encourage an efficient photosynthetic reaction and induced flowering, so the plant will have early initiation of flower bud and fruiting (Kota et al., 2022). It is matched with our results that the average leaf area was correlated positively with the number of flowers per plant ($r=0.735$, $p<0.001$) and correlated negatively with days to first flowering ($r=-0.325$,

$p<0.05$). In short, the oil palm waste compost was proven that it can increase average leaf area better than NPK fertilizer and control.

5.2.2 Average Plant Height (cm) and Average Stem Diameter (mm)

The average plant height and average stem diameter showed that T4 had higher plant height and stem diameter than T2, followed by T3 and T1. The application of T4 had greatly improved soil fertility, followed by T2. Previous research demonstrated that the application of poultry manure performed better in terms of okra height, and stem diameter compared to NPK fertilizer and control without fertilization (Muhammad, Kutawa and Adamu, 2020). The cassava peel compost also had highest value in okra stem diameter compared to NPK and control without fertilization (Ruth et al., 2017). In summary, the oil palm waste compost was proven that it can increase average plant height and stem diameter better than NPK fertilizer and control.

5.3. Yield Parameters

5.3.1 Total Fresh Pod Yield and Total Dry Pod Yield (g)

Total fresh pod yield and total dry pod yield are higher in T4 compared to T2, followed by T1 and T2. The study by Kota et al. (2022) and Ofosu-Anim, Blay and Frempong, (2006) showed that the organic fertilizer can significantly improve the fresh pod yield of okra compared to its control. To support our result, the poultry manure and NPK fertilizer can significantly increase the okra pod yield per ha compared to control (Muhammad et al., 2020). At the same time, the NPK fertilizer also can increase the okra pod yield per ha (Muqtadir et al., 2019). In short, the oil palm waste compost and NPK fertilizer was able to increase total fresh pod yield and total dry pod yield.

5.3.2 Average Fresh Pod Weight and Average Dry Pod Weight (g)

In Figure 4.10, the average fresh pod weight and average dry pod weight are higher in T4 than T2, followed by T3 and T1. The application of organic fertilizer increased the plant yield. Applying kitchen compost had okra higher dry pod yield compared to NPK fertilizer (Abbas et al., 2019). Similarly, litter compost resulted in the highest average dry pod weight compared to NPK fertilizer and control (Attarde et al., 2012). The higher pod weight may be due to the acceleration of source to sink in photosynthesis reaction as that is also affected by growth hormones such as auxin, gibberellin (Bot, Benites and Rome, 2005), indoleacetic acid and cytokinin released (Weil and Brady, 2017) from decomposition of organic matter (Kota et al., 2022). In summary, the oil palm waste compost was proven that can increase average fresh pod weight and average dry pod weight better than NPK fertilizer and control.

5.3.3 Days to First Flowering and Average Number of Flowers per Plant

The Figure 4.11 showed that T4 and T2 had lower days to first flowering compared to T1 and T3 even there are no significant different among the treatment. As mentioned in discussion of average leaf area, increasing leaves may encourage more photosynthetic reaction and induced early flowering, so the plant will have early initiation of flower bud (Kota et al., 2022). In study of Muhammad et al., (2020), compost had significantly lower days to first flowering day than NPK fertilizer on okra.

Regarding the average number of flowers per plant, according to the Figure 4.12, it showed a result of T4 higher than T2, followed by T3 and T1. To support the result, there are similar results from other researchers. NPK fertilizer application significantly affected the number of flower per plant from 6.2 to 11.8 in okra plant (Khandaker et al., 2017). The researchers also found that the farmyard manure had higher number of flowers per plant than NPK and control (Attarde et al., 2012). In summary, the oil palm waste compost and NPK fertilizer were proven that it can reduce days to first flowering and increase average number of flowers per plant.

5.4 Summary of Vegetative Parameters and Yield Parameters

Overall, the oil palm waste compost (Baba) had proven that it can increase average of leaf area, plant height, stem diameter, dry plant weight, dry root weight, fresh pod weight and dry pod weight as well as total fresh pod yield, total dry pod yield, and average number of flowers per plant compared to FFPW, NPK fertilizer, and control with no fertilization. Oil palm waste compost (Baba) is the best fertilizer to amend the ex-tin mining in this study, followed by NPK fertilizer and FFPW.

5.5 Profits

According to Table 4.6, if all the okra pod is sold as non-organic okra, the T1, T2 and T3 has a gain profit from the farming okra with the treatments. However, T4 showed a loss from the farming okra with the treatment. Therefore, it will not be the choice of fertilizer for farmers. The NPK fertilizer is the most cost-effective fertilizer for the farmers. Hence, different doses at fertilizer should be tested to determinate which dose give the highest yield and profit. However, if the okra is sold as organic okra, T4 has the highest profit, followed by T2, T1 and T3. It is suggested that farmers farming with organic fertilizers try to get the organic certificate to increase the market value of agricultural product and have better income. However, the maintenance cost of farming activities like irrigation, and labor cost were not included in this study. In reality, an organic farm may have other high-cost practices which need to be covered, like application of organic pesticides and hand weeding. Therefore, it is not possible to conclude that the farmers can gain high profit from the sale of organic okra. Yet, there are no available information about actual production cost for the commercial okra farming on ex-mining soil.

5.6 Recommendations for Future Studies

It is recommended to do open field evaluation for NPK fertilizers, fermented fruit peel waste, and oil palm waste composts because polybags have a limit space for plant growth. According to (Zakaria et al., 2021), the chilies grew in 27 cm × 27 cm and 17 cm × 17 cm polybags will have 32% increment and 32% reduction of fruit fresh weight compared to chilies grew in 19 cm × 19 cm polybags. The high overlapping root zone in small container size leads to low nutrients acquisition and oxygen deficiency that inhibits root and shoot growth (Tanyaradzwa et al., 2015). Since nitrogen, phosphorus and potassium are important macronutrients for plant growth and yield, the NPK nutrient~~s~~ content of sample soil and plant should be examined for each treatment to investigate the nutrient uptake efficiency of plants from the soil. The NPK analysis is suggested to follow the standard methods: testing total N with Kjeldahl method (Jones, 2001), test dissolved P by referring the method mentioned in Ganesh et al., (2012) with UV-VIS spectrophotometry set at 830 nm with its blank, and exchangeable K tested by method in Kulkarni, Warhade and Bahekar, (2014) with UV-VIS spectrophotometry set at 230 nm with its blank.

CHAPTER 6

CONCLUSION

In summary, the results indicated that T4 significantly improved the vegetative growth and yield of okra. The vegetative and yield parameters such as average of leaf area, plant height, stem diameter, dry plant weight, dry root weight as well as total fresh pod yield, total dry pod yield and average number of flowers per plant are significantly higher in T4 compared to T2, followed by T1 and T3. There was no significant difference in the vegetative parameters measured for T3 and T1. The average fresh pod weight and average dry pod weight has a result of T4 significantly higher than T2, followed by T3 and T1. The days to first flowering for T4 and T2 was higher than T1 and T3. For soil fertility parameters, T4 improved the soil fertility of the ex-tin mining soil by decreasing the soil pH value, increasing soil electrical conductivity (EC), and maintaining the soil organic carbon (SOC) concentration. Hence, the application of oil palm waste compost is recommended for improving soil fertility, growth and yield of crops cultivated on ex-tin mining soil, because organic matter helps the soil to hold nutrients, water and thus, help plants to uptake nutrients easily.

Overall, we concluded that the oil palm waste compost is the best fertilizers to the ex-mining soil, followed by NPK fertilizer and fermented fruit peel waste. The application of compost improved soil fertility, growth and yield of okra on ex-tin mining soil better than NPK fertilizer, and fermented fruit peel waste, because organic matter helps the soil to hold nutrients and water, which improves plant nutrient uptake.

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APPENDIX A

Figure 1: The photo of NPK fertilizer used in this study (15:15:15) with a front view (Twin Arrow Fertilizer Sdn. Bhd., n.d).

Figure 2: The photo of homemade fermented fruit peel waste used in this study.

Figure 3: The photo of Baba compost used in this study with a) a front and b) back view.

Table 1: Composition of the Baba compost.

Description	Percentage (%)
pH	7.5
Organic matter content	>50 (dry matter)*
Nitrogen	>2
Phosphorus	>2
Potassium	>1.5
Calcium+Magnesium+Trace elements	>5
C/N ratio	>17
Moisture content	>25

*Main materials: oil palm meals and other fibrous material (not listed).

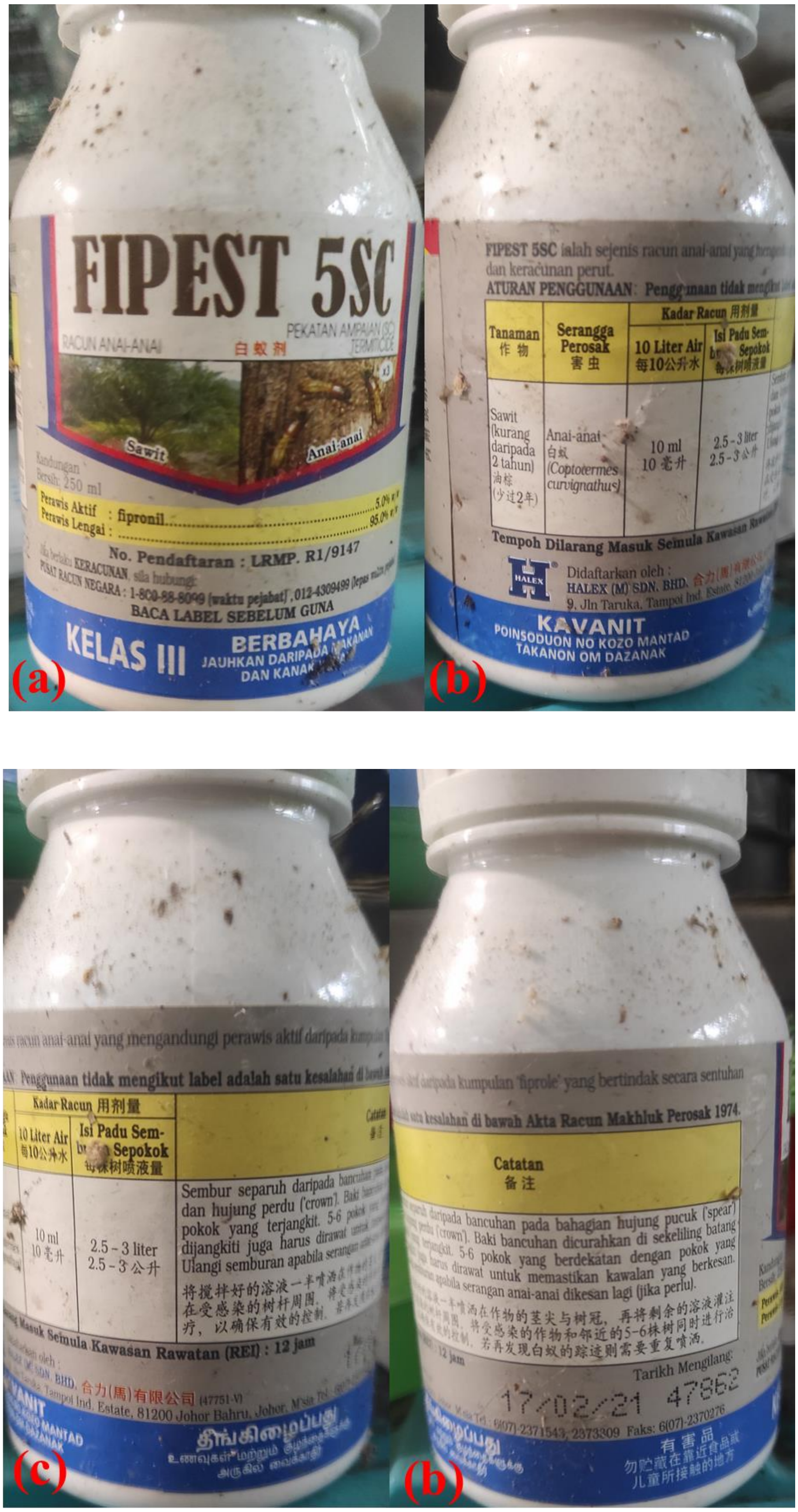


Figure 2: The photo of pesticides (fipronil) with a) front and b) back view 1 c) back view 2 and b) back view 3.

APPENDIX B

Figure 1: The picture of crops at Day 30 from the view of front side.

Figure 2: The picture of crops at Day 60 from the front view from the view of front side.

Figure 3: The picture of crops at Day 90 from front view from the view of front side.

Figure 4: The pictures of whole okra plant (T1) at Day 90 on a stones tile.

Figure 5: The pictures of whole okra plant (T2) at Day 90 on stones tiles.

Figure 6: The pictures of whole okra plant (T3) at Day 90 on a stones tile.

Figure 7: The pictures of whole okra plant (T4) at Day 90 on stones tiles.

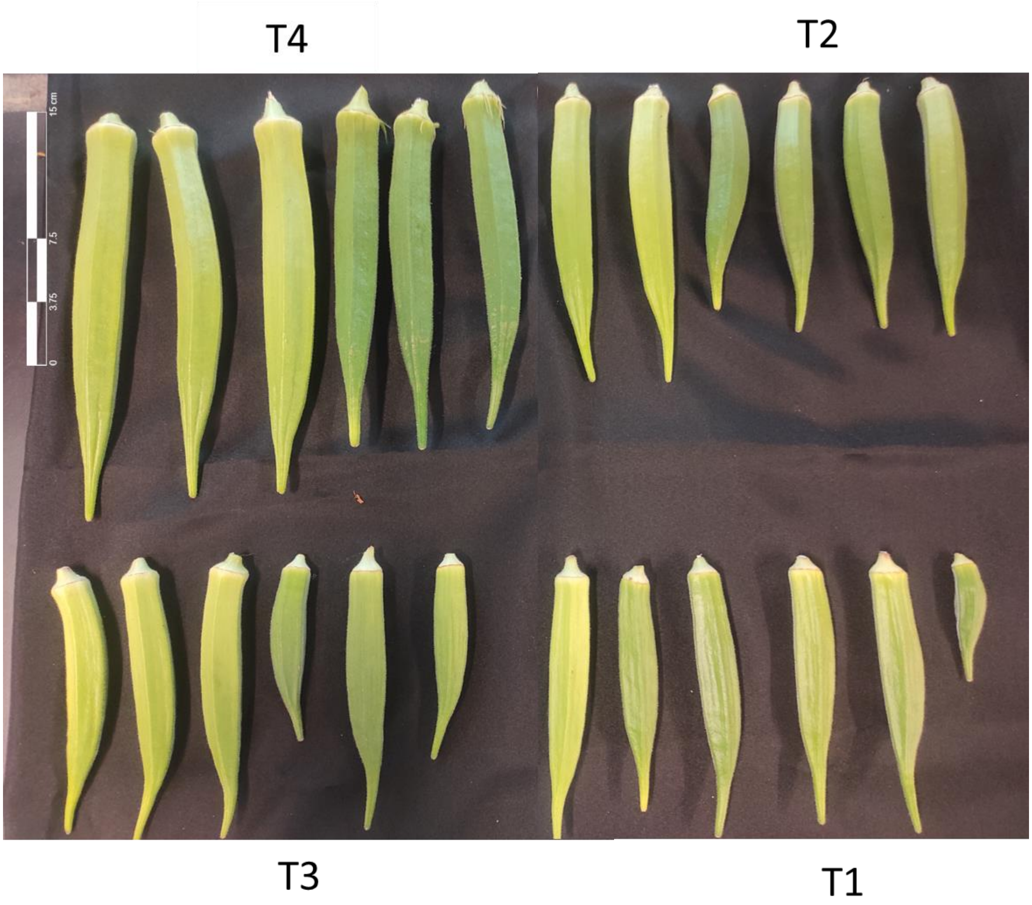
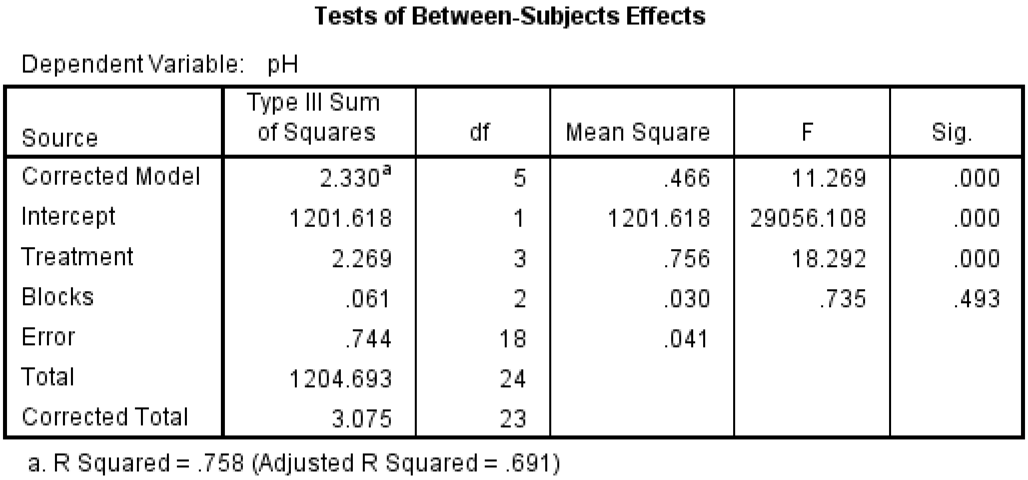


Figure 8: The picture of okra fruit size with a 15 cm scale bar as referring size. T1=Control, T2=NPK fertilizer, T3=Fermented fruit peel waste, T4=Oil palm waste compost (Baba).

APPENDIX C



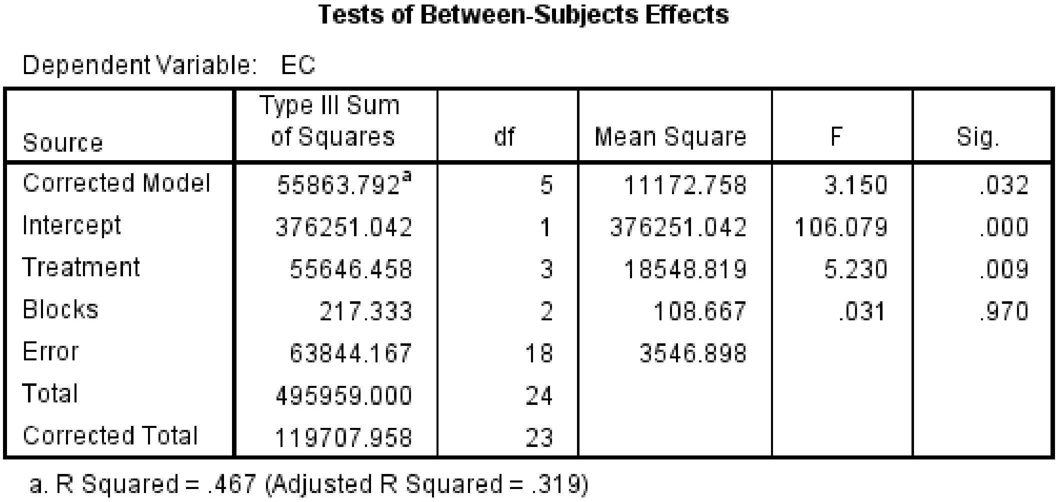
Tests of Between-Subjects Effects

Dependent Variable: pH

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2.330[a]	5	.466	11.269	.000
Intercept	1201.618	1	1201.618	29056.108	.000
Treatment	2.269	3	.756	18.292	.000
Blocks	.061	2	.030	.735	.493
Error	.744	18	.041		
Total	1204.693	24			
Corrected Total	3.075	23			

a. R Squared = .758 (Adjusted R Squared = .691)

Figure 1: Statistical analysis of soil pH under different fertilizer treatments: Univariate analysis, significant difference, $p \leqslant 0.05$. *There was significant difference in the soil pH under different fertilizer treatments.



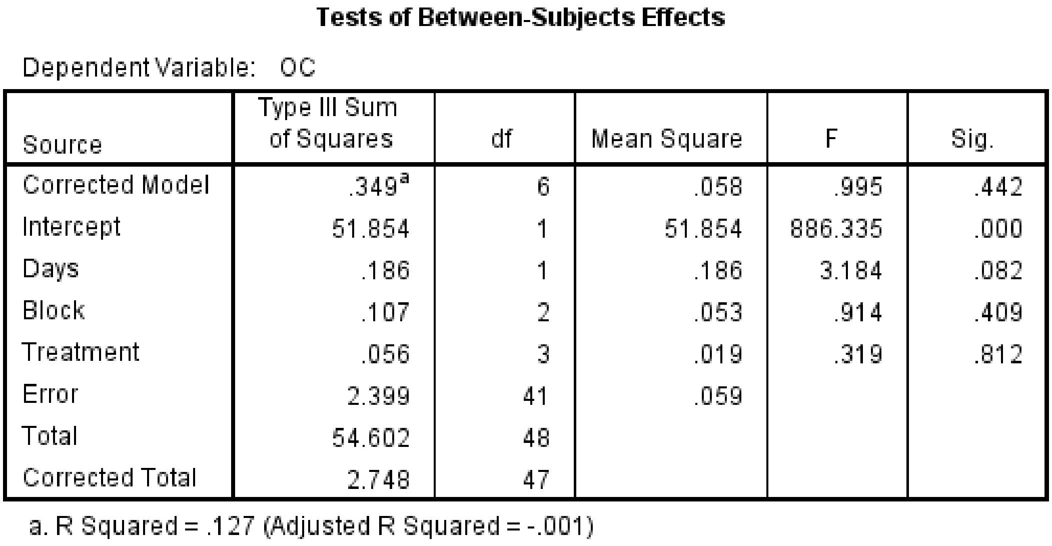
Tests of Between-Subjects Effects

Dependent Variable: EC

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	55863.792[a]	5	11172.758	3.150	.032
Intercept	376251.042	1	376251.042	106.079	.000
Treatment	55646.458	3	18548.819	5.230	.009
Blocks	217.333	2	108.667	.031	.970
Error	63844.167	18	3546.898		
Total	495959.000	24			
Corrected Total	119707.958	23			

a. R Squared = .467 (Adjusted R Squared = .319)

Figure 2: Statistical analysis of soil EC under different fertilizer treatments: Univariate analysis, significant difference, $p \leqslant 0.05$. *There was significant difference in the soil EC under different fertilizer treatments.



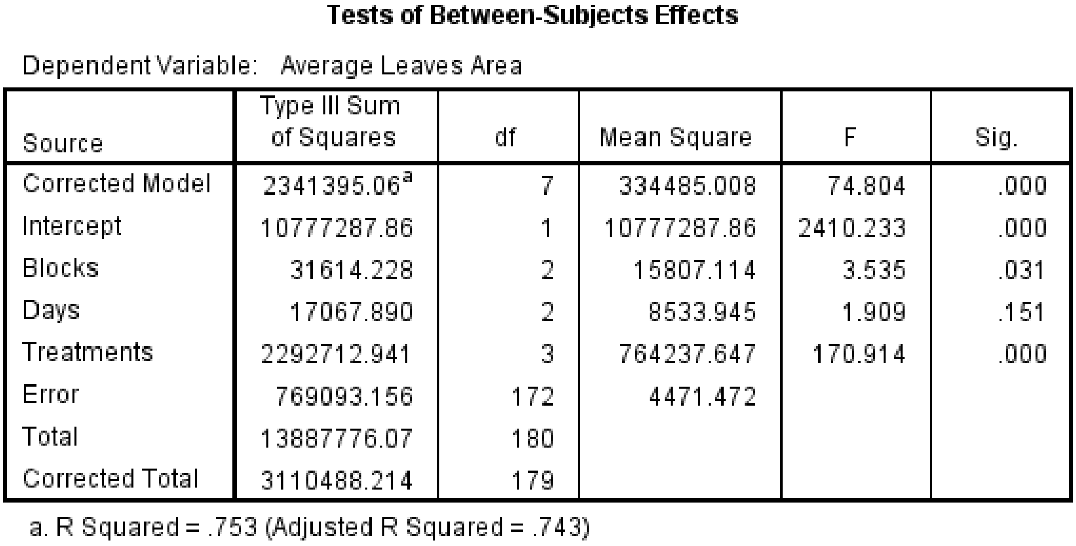
Tests of Between-Subjects Effects

Dependent Variable: OC

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.349[a]	6	.058	.995	.442
Intercept	51.854	1	51.854	886.335	.000
Days	.186	1	.186	3.184	.082
Block	.107	2	.053	.914	.409
Treatment	.056	3	.019	.319	.812
Error	2.399	41	.059		
Total	54.602	48			
Corrected Total	2.748	47			

a. R Squared = .127 (Adjusted R Squared = -.001)

Figure 3: Statistical analysis of soil organic carbon concentration (SOC) under different fertilizer treatments: Univariate analysis, significant difference, $p \leqslant 0.05$. *There was no significant difference in the soil organic carbon concentration under different fertilizer treatments.



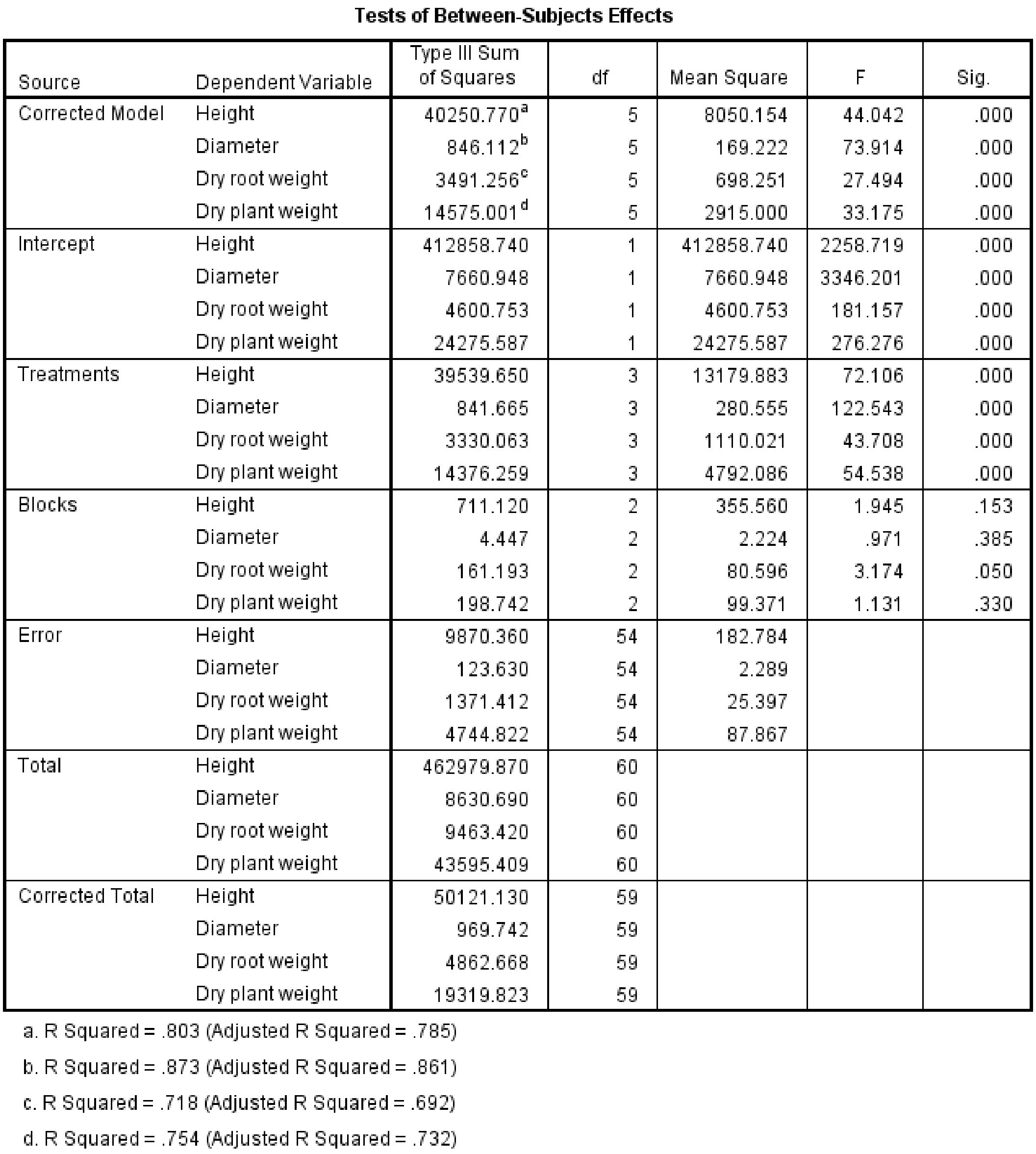
Tests of Between-Subjects Effects

Dependent Variable: Average Leaves Area

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2341395.06[a]	7	334485.008	74.804	.000
Intercept	10777287.86	1	10777287.86	2410.233	.000
Blocks	31614.228	2	15807.114	3.535	.031
Days	17067.890	2	8533.945	1.909	.151
Treatments	2292712.941	3	764237.647	170.914	.000
Error	769093.156	172	4471.472		
Total	13887776.07	180			
Corrected Total	3110488.214	179			

a. R Squared = .753 (Adjusted R Squared = .743)

Figure 4: Statistical analysis of average leaf area under different fertilizer treatments: Univariate analysis, significant difference, $p \leqslant 0.05$. *There was significant difference in the average leaf area under different fertilizer treatments.



Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	Height	40250.770[a]	5	8050.154	44.042	.000
	Diameter	846.112[b]	5	169.222	73.914	.000
	Dry root weight	3491.256[c]	5	698.251	27.494	.000
	Dry plant weight	14575.001[d]	5	2915.000	33.175	.000
Intercept	Height	412858.740	1	412858.740	2258.719	.000
	Diameter	7660.948	1	7660.948	3346.201	.000
	Dry root weight	4600.753	1	4600.753	181.157	.000
	Dry plant weight	24275.587	1	24275.587	276.276	.000
Treatments	Height	39539.650	3	13179.883	72.106	.000
	Diameter	841.665	3	280.555	122.543	.000
	Dry root weight	3330.063	3	1110.021	43.708	.000
	Dry plant weight	14376.259	3	4792.086	54.538	.000
Blocks	Height	711.120	2	355.560	1.945	.153
	Diameter	4.447	2	2.224	.971	.385
	Dry root weight	161.193	2	80.596	3.174	.050
	Dry plant weight	198.742	2	99.371	1.131	.330
Error	Height	9870.360	54	182.784		
	Diameter	123.630	54	2.289		
	Dry root weight	1371.412	54	25.397		
	Dry plant weight	4744.822	54	87.867		
Total	Height	462979.870	60			
	Diameter	8630.690	60			
	Dry root weight	9463.420	60			
	Dry plant weight	43595.409	60			
Corrected Total	Height	50121.130	59			
	Diameter	969.742	59			
	Dry root weight	4862.668	59			
	Dry plant weight	19319.823	59			

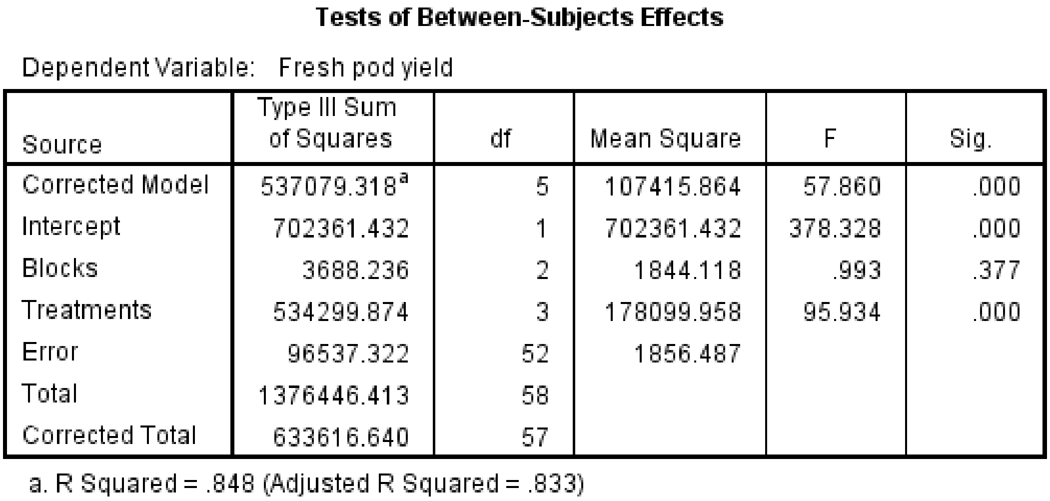
a. R Squared = .803 (Adjusted R Squared = .785)

b. R Squared = .873 (Adjusted R Squared = .861)

c. R Squared = .718 (Adjusted R Squared = .692)

d. R Squared = .754 (Adjusted R Squared = .732)

Figure 5: Statistical analysis of average plant height, average stem diameter, average dry root weight, and average dry plant weight and under different fertilizer treatments: Multivariate analysis, significant difference, $p \leqslant 0.05$. *There was significant difference in the average plant height, average stem diameter, average dry root weight, and average dry plant weight under different fertilizer treatments.



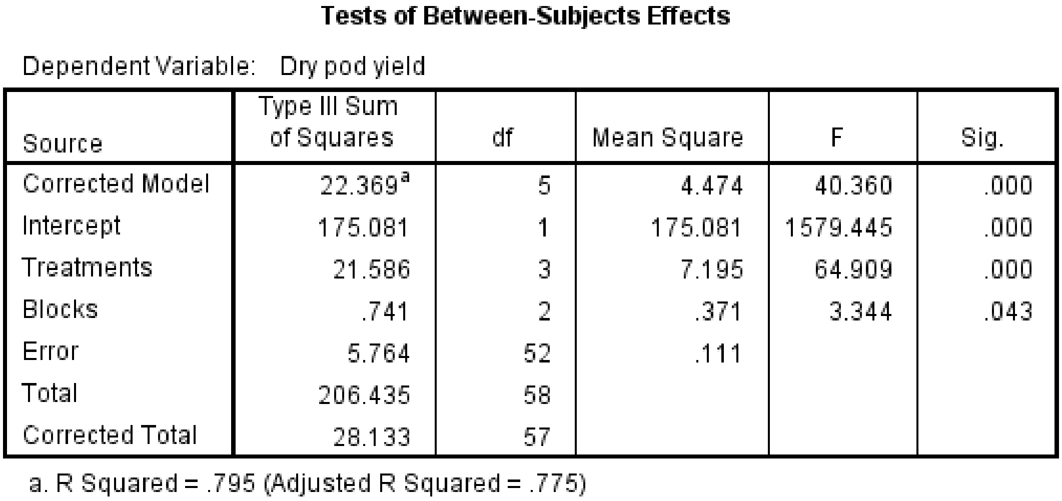
Tests of Between-Subjects Effects

Dependent Variable: Fresh pod yield

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	537079.318[a]	5	107415.864	57.860	.000
Intercept	702361.432	1	702361.432	378.328	.000
Blocks	3688.236	2	1844.118	.993	.377
Treatments	534299.874	3	178099.958	95.934	.000
Error	96537.322	52	1856.487		
Total	1376446.413	58			
Corrected Total	633616.640	57			

a. R Squared = .848 (Adjusted R Squared = .833)

Figure 6: Statistical analysis of total dry pod yield under different fertilizer treatments: Univariate analysis, significant difference, $p \leqslant 0.05$. *There was significant difference in the total dry pod yield under different fertilizer treatments.



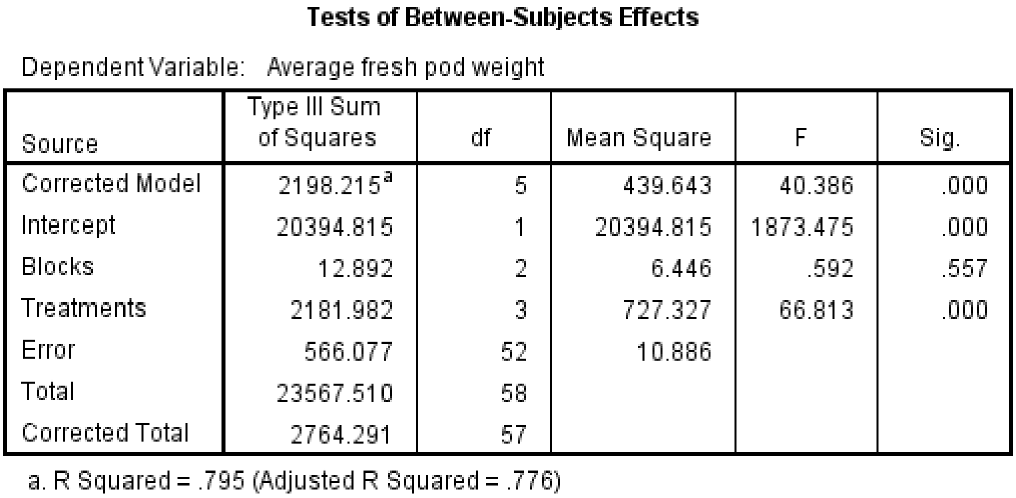
Tests of Between-Subjects Effects

Dependent Variable: Dry pod yield

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	22.369[a]	5	4.474	40.360	.000
Intercept	175.081	1	175.081	1579.445	.000
Treatments	21.586	3	7.195	64.909	.000
Blocks	.741	2	.371	3.344	.043
Error	5.764	52	.111		
Total	206.435	58			
Corrected Total	28.133	57			

a. R Squared = .795 (Adjusted R Squared = .775)

Figure 7: Statistical analysis of total dry pod yield under different fertilizer treatments: Univariate analysis, significant difference, $p \leqslant 0.05$. *There was significant difference in the total dry pod yield under different fertilizer treatments.



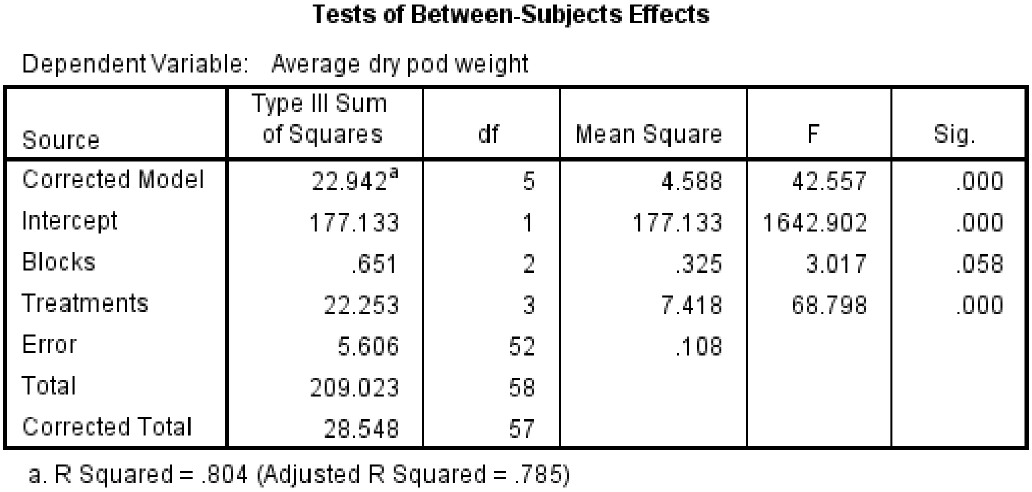
Tests of Between-Subjects Effects

Dependent Variable: Average fresh pod weight

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2198.215[a]	5	439.643	40.386	.000
Intercept	20394.815	1	20394.815	1873.475	.000
Blocks	12.892	2	6.446	.592	.557
Treatments	2181.982	3	727.327	66.813	.000
Error	566.077	52	10.886		
Total	23567.510	58			
Corrected Total	2764.291	57			

a. R Squared = .795 (Adjusted R Squared = .776)

Figure 8: Statistical analysis of average fresh pod weight under different fertilizer treatments: Univariate analysis, significant difference, $p \leqslant 0.05$. *There was significant difference in the average fresh pod weight under different fertilizer treatments.



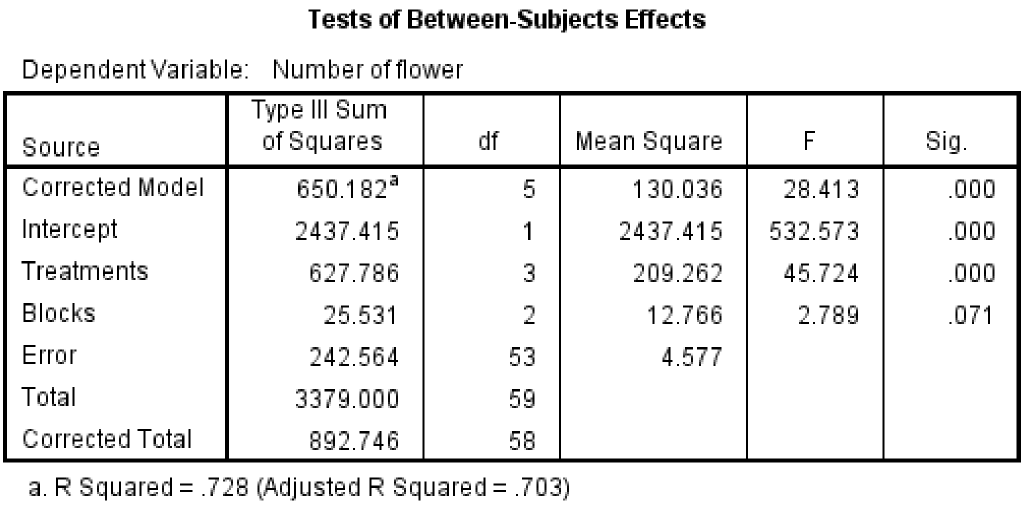
Tests of Between-Subjects Effects

Dependent Variable: Average dry pod weight

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	22.942[a]	5	4.588	42.557	.000
Intercept	177.133	1	177.133	1642.902	.000
Blocks	.651	2	.325	3.017	.058
Treatments	22.253	3	7.418	68.798	.000
Error	5.606	52	.108		
Total	209.023	58			
Corrected Total	28.548	57			

a. R Squared = .804 (Adjusted R Squared = .785)

Figure 9: Statistical analysis of average dry pod weight under different fertilizer treatments: Univariate analysis, significant difference, $p \leqslant 0.05$. *There was significant difference in the average dry pod weight under different fertilizer treatments.



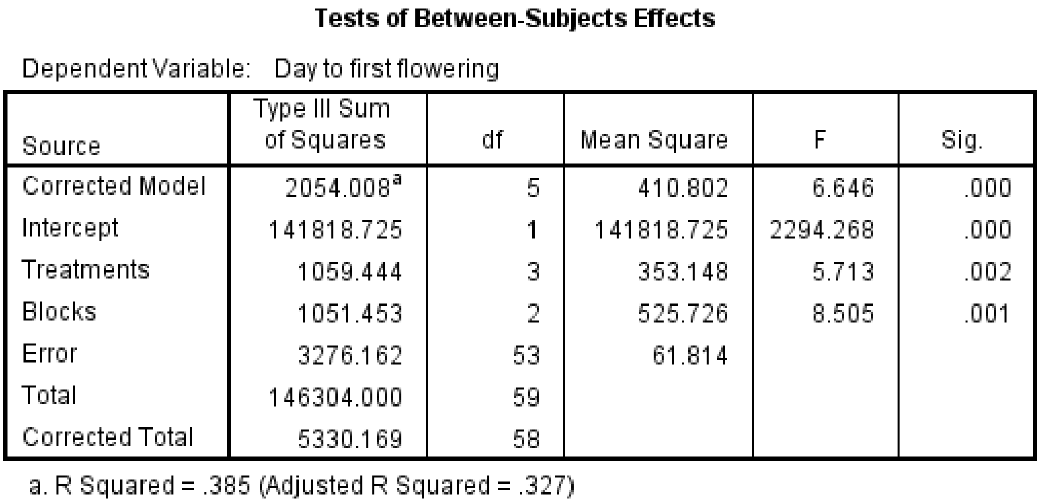
Tests of Between-Subjects Effects

Dependent Variable: Number of flower

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	650.182[a]	5	130.036	28.413	.000
Intercept	2437.415	1	2437.415	532.573	.000
Treatments	627.786	3	209.262	45.724	.000
Blocks	25.531	2	12.766	2.789	.071
Error	242.564	53	4.577		
Total	3379.000	59			
Corrected Total	892.746	58			

a. R Squared = .728 (Adjusted R Squared = .703)

Figure 10: Statistical analysis of number of flowers per plant under different fertilizer treatments: Univariate analysis, significant difference, $p \leqslant 0.05$. *There was significant difference in the number of flowers per plant under different fertilizer treatments.



Tests of Between-Subjects Effects

Dependent Variable: Day to first flowering

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2054.008[a]	5	410.802	6.646	.000
Intercept	141818.725	1	141818.725	2294.268	.000
Treatments	1059.444	3	353.148	5.713	.002
Blocks	1051.453	2	525.726	8.505	.001
Error	3276.162	53	61.814		
Total	146304.000	59			
Corrected Total	5330.169	58			

a. R Squared = .385 (Adjusted R Squared = .327)

Figure 11: Statistical analysis of days to first flowering under different fertilizer treatments: Univariate analysis, significant difference, $p \leqslant 0.05$. *There was significant difference in the days to first flowering under different fertilizer treatments.

Table 1: Pearson correlation coefficients for all the parameters.

	FA	**PH**	**SD**	**DPW**	**DRW**	**TFPW**	**TDPW**	**AFPW**	**ADPW**	**DFF**	**NOF**
LA	1										
PH	.735**	1									
SD	.760**	.784**	1								
DPW	.762**	.798**	.828**	1							
DRW	.704**	.822**	.827**	.854**	1						
TFPY	.756**	.901**	.803**	.768**	.844**	1					
TDPY	.700**	.879**	.779**	.743**	.834**	.983**	1				
AFPW	.669**	.719**	.894**	.690**	.731**	.778**	.740**	1			
ADPW	.653**	.720**	.870**	.676**	.743**	.798**	.793**	.955**	1		
DFF	-.325*	-.419**	-.276*	-.282*	-.349**	-.506**	-.469**	-.214	-.239	1	
NOF	.734**	.857**	.710**	.726**	.770**	.928**	.906**	.611**	.625**	-.640**	1

Asterisks ** indicates the significant correlation at the 0.01 level (2-tailed).
Asterisk * indicates the significant correlation at the 0.05 level (2-tailed).
LA=Average leaf area; PH=Average plant height; SD=Average stem diameter; DPW=Average plant weight; DRW=Average root weight; TFPY=Total fresh pod yield; TDPY= Total fresh pod yield; AFPW=Average fresh pod weight; ADPW=Average dry pod weight; DFF=Days to first flowering; NOF=Average number of flowers per plant.