EFFECTS OF [illegible] ORGANIC FERTILIZERS ON GROWTH AND POSTHARVEST QUALITY OF CHINESE VEGETABLE (*Brassica rapa* L.)

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2010

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Effects of organic and inorganic fertilizers on growth and post-harvest quality of chinese vegetable (Brassica rapa L.) / Le Wei Shin.

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EFFECTS OF ORGANIC AND INORGANIC FERTILIZERS ON GROWTH AND POST-HARVEST QUALITY OF CHINESE VEGETABLE (*Brassica rapa* L.)

By
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Research Report submitted in partial fulfilment of
the requirements for the degree of
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Department of Agrotechnology
FACULTY OF AGROTECHNOLOGY AND FOOD SCIENCE
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ENDORSEMENT

The project report entitled **Effects of organic and inorganic fertilizers on growth and post-harvest quality of Chinese vegetable (*Brassica rapa* L.)** by **Lee Wei Shin**, Matric No**. UK 15331** has been reviewed and corrections have been made according to the recommendations by examiners. This report is submitted to the Department of Agrotechnology in partial fulfilment of the requirements for the degree of Bachelor of Science Agrotechnology (Post Harvest Technology), Faculty of Agrotechnology and Food Science, Universiti Malaysia Terengganu.

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DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledge.

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ABSTRACT

A dwarf type Pak Choi (*Brassica rapa* L.) was cultivated using sandy loam soil in a greenhouse. Organic and inorganic fertilizer treatments were tested for their effects on the growth and post-harvest quality of the vegetables. Four commercial fertilizer treatments including chicken manure (CKN), vermicompost (VER), foliar biofertilizer (FOL), chemical fertilizer (CHE) and control treatment with no fertilizer (CTL) were applied at their respective recommended rates. Assessment was done on the growth parameter, visual quality of the vegetables, colour, plant pigments, firmness, and nutrients contents of the plants. The results show that the growth and post-harvest quality of the vegetables were significantly affected by different types of fertilizer. CHE had advantages over other treatments in attaining maximum growth and high essential nutrient levels but exhibited poor visual quality and low firmness of the leaves. The organic fertilizers gave marginal effects on the nutrients contents of plants, except FOL had positive effects on P, Ca, Mg, Cu, Fe and Mn contents of the plants. Overall, VER and FOL were not able to enhance the growth and quality of *B. rapa*. CKN has significantly enhanced the visual appearance and firmness of leaves better than other treatments, thereby serving as good attributes for consumers to choose organic vegetables instead of conventionally grown vegetables.

ABSTRAK

Sawi Jepun (*Brassica rapa* L.) ditanam dengan menggunakan tanah lempung berpasir di rumah hijau. Kesan pembajaan organik dan pembajaan kimia dikaji terhadap pertumbuhan dan kualiti lepas tuai sawi. Tiga jenis baja organik iaitu tahi ayam (CKN), vermikompos (VER), biobaja untuk aplikasi daun (FOL), baja kimia (CHE) dan kawalan tanpa baja (CTL) ditabur ke dalam tanah pada kadar yang disyorkan masing-masing. Penilaian dilakukan ke atas parameter pertumbuhan, kualiti visual sawi, warna, pigmen tumbuhan, kesegahan dan nutrien dalam sawi. Keputusan kajian menunjukkan bahawa pertumbuhan dan kualiti lepas tuai sawi adalah dipengaruhi oleh jenis pembajaan yang berbeza. CHE mempunyai kelebihan dalam mencapai pertumbuhan maksimum dan kandungan nutrien yang tinggi berbanding baja yang lain tetapi mempunyai kualiti visual dan kesegahan daun yang rendah. Pembajaan organik menunjukkan kesan yang kurang ketara pada kandungan nutrien sawi, kecuali FOL yang mempunyai kesan positif dari segi kandugan P, Ca, Mg, Cu, Fe dan Mn dalam tumbuhan. Secara keseluruhannya, VER dan FOL tidak dapat meningkatkan pertumbuhan dan kualiti lepas tuai sawi. CKN dapat meningkatkan kualiti visual dan kesegahan daun lebih baik berbanding dengan baja lain, dan seterusnya menjadi sesuatu daya tarikan penting untuk menggalakan pelanggan memilih sayur-sayuran organik.

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ANOVA	Analysis of Variance
CTL	Control
CKN	Chicken manure
VER	Vermicompost
FOL	Foliar biofertilizer
CHE	Chemical fertilizer
µg/ml	microgram per milliliter
ppm	part per million
t/ha/season	tonnes per hectare per season
%	Percentage
g	Gram
Abs	absorption
°C	Degree Celsius
±	More or less
<	Less than
>	More than

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CHAPTER 1

INTRODUCTION

1.1 Background of study

Chinese vegetables are always in high demand in local market and for export to neighbouring countries in Asia. According to Hill (1990), even in Australia, although Chinese vegetables are new but they are in increasing demand and have potential for export to Southeast Asia. To ensure their commercial viability, the intensive cultivation to produce vegetables with high yields and quality are critical. Chemical fertilizers seem to be the popular choice for soil fertility amendment in vegetable cultivation, but new awareness arises regarding the health concern and food safety of conventionally grown vegetables. The demand of organically grown vegetables is increasing as the consumers with higher income have general preferences over organic produce. The changing trend of demand on vegetables gives an impetus for the development of organic farming. Many vegetable producers have started to go for organic farming or organic fertilization to meet the increasing demand of organic produces.

Application of fertilizers during crop production is essential to produce vegetables of high yields and quality. Fertilizers are compounds applied to promote plant growth; it can be divided into organic fertilizers and inorganic fertilizers. Organic fertilization was traditionally and preferentially used in crop production in developing country until 1960's when inorganic or chemical fertilizers began to gain popularity (Sharma, 2002). On the other hand, inorganic fertilizers which are composed of chemicals and minerals are added into the soil to meet high nutrient requirements for target yield of crops. The inorganic fertilizers are widely used in intensive vegetable cultivation because it is highly accessible and relatively easy to be applied into the farms. The inorganic fertilization is easy and convenient, but it is high in cost (Novizan and Faridah, 2007). Comparatively, the organic fertilizers need to go through a time-consuming compost process before it is applied to the farms, despite of the advantages of soil improvement properties. There are a wide variety of organic fertilizers available for agricultural production nowadays. It basically includes all fertilizers that are not of synthetic or chemicals based, which derives from composted crop residues, farmyard manure, and other sources of plant and animal wastes. Organic fertilizers are also associated with biofertilizers which make use of earthworms and beneficial microorganisms for plants.

Inorganic fertilizers are commonly used to treat fields used for growing maize, followed by barley, sorghum, rapeseed, soy and sunflower. The application of nitrogen fertilizer on off-season cover crops can increase the biomass, and subsequent green manure value of these crops, while having a beneficial effect on soil nitrogen levels for the main crop planted during the summer season. However, many inorganic fertilizers do not replace trace mineral elements in the soil which become gradually depleted by crops. This depletion has been linked to studies which have shown a marked fall in the quantities of such minerals present in fruit and vegetables. Meanwhile, nutrients provides by inorganic fertilizers are easily leached causing excessive loss during crop production.

Animal manures are demonstrated to be the excellent organic nutrient sources for vegetable cultivation (Aini *et al.*, 2005). Among them, poultry manure contains highest percentage of nitrogen, phosphorous & potassium (Sharma, 2002). Vermicompost produced by earthworms can give nutrient balance and also additional phytohormones to the plants. Although its macronutrients are lower compared to chemical fertilizer, but it is rich in micronutrients and trace elements (Hasnah, 2003). Vermicompost and liquid vermicompost leachate are gaining popularity among farmers to grow crops; it provides micronutrients, humic and fulvic acid that can stimulate plant development (Antonio *et al.*, 2008). Vermicompost also acts as soil buffer to cure acidity, heavy metal reducer, growth enhancer (Hasnah, 2003). Biofertilizers contain microbial inoculants which are used to provide nutrients to plants. It increases soil nutrients and improves the efficient of nutrition uptake by plants. Previous study suggested that the plants' biochemical and morphological characters will be improved significantly when treated with biofertilizers. It can be applied as foliar feeding on plant leaves. Foliar feeding has advantages of fast mechanism of absorption and nutrient readily used by the leaves (Novizan and Faridah, 2007).

1.2 Problem statement

Generally, people believe that vegetables grown with organic fertilization has better quality, taste and more nutritious than those with inorganic fertilization. However the statement of better quality in vegetables grown with organic fertilization is often solely based on eating quality of vegetables. Previous studies have been done on vegetables from retailers, vegetables from experimental field and vegetables collected from organic and conventional farms. However, the differences in physical properties and nutrient contents of organic and inorganic fertilized vegetables have shown varied and controversial results.

1.3 Significance of study

Most of previous studies were done on crops such as maize, lettuce, cabbage, potatoes, carrots, etc. These studies were conducted under field conditions which are affected by environmental factors such as soil types, weather conditions and history of cropping system. The effect of organic and inorganic fertilizers on the post-harvest quality of *Brassica rapa* remain a myth although it is one of the leafy vegetable crops with high demand. Therefore, this study is designed to eliminate these environmental factors that can influence the performance of crops when being applied with different types of fertilizers. Moreover, a scientific method is applied in this study, in terms of post-harvest analysis to find out whether *B. rapa* grown with organic fertilization has better quality than those grown with inorganic fertilization.

1.4 Objective

The aim of this study was to determine the effects of different types of fertilizers including chicken manure, vermicompost, biofertilizer and chemical fertilizer on the growth and post-harvest quality of *Brassica rapa.*

CHAPTER 2

LITERATURE REVIEW

2.1 Pak Choi (*Brassica rapa* L.)

The term Chinese vegetables refer to *Brassica* family, which include Kai lan (*Brassica alboglabra,* Bailey), Tsoi sum (*Brassica parachinesis,* Bailey), Pak Choi (*Brassica rapa* L. *or Brassica chinensis* L. Bailey), etc. *Brassica rapa* is a perennial plant grown commercially, it is commonly known as Bai Cai, sawi putih or Chinese Chard. The taxonomy of the genus *Brassica* crop is complicated. *Brassicaceae* (equivalent *Cruciferae*) family comprises several crops known under generic name of cole crops, including cabbage and kale. Modern classifications of the family *Brassicaceae* are based on a review by Schultz (1936) who reduced the number of tribes from nineteen to fifteen, nowadays the number of tribes commonly accepted is thirteen. The species within the *Brassicaceae* have a floral structure consisting of four sepals, four petals, six stamens (four long and two short) and a gynoecium form by two carpels and a superior ovary. The fruit is a capsule (siliqua) divided into two locula by a septum. U (1935) studied the cytology of the genus and established the relationships among the genomes of the six species *Brassica* genus with greatest agricultural importance all over the world (Figure 2.1).

Brassica rapa is grown extensively throughout Asia with a huge number of distinct varieties. Differentiation results from selection both in nature and by the

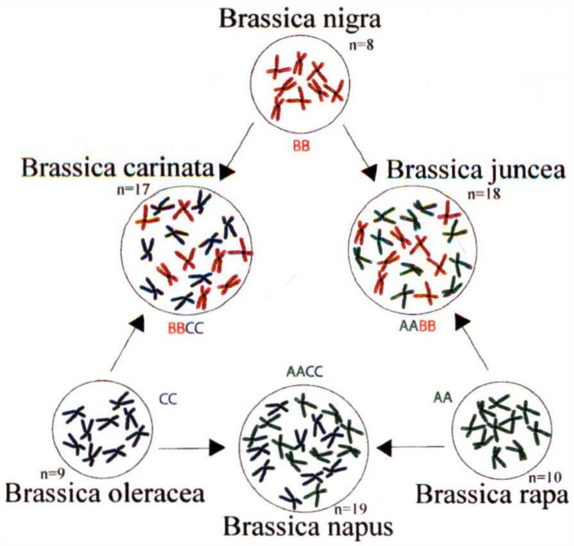

Figure 2.1: U triangle showing the relationships between the cultivated species of the genus *Brassica* (Source: U, 1935).

forces of cultivation with great mingling and recombination. Initially the centre of origin of *B. rapa* is postulated as the Mediterranean from where it spread northwards to Scandinavia and eastwards to Germany and into Central Europe, and eventually towards Asia (Mizushima and Tsunoda, 1967). The plant reached China via Mongolia as an agricultural crop and was introduced to Japan. In India, *B. rapa* and *B. rapa* var. *sarson* are used as oil plant. Along the way, great local variation in cultivation had developed as the species spread (Dixon, 2004).

Brassica rapa now is a leafy vegetable commonly used in Chinese and South-east Asian cooking. It has a firm white stem, dark green leaves, and a faintly bitter taste. *B. rapa* is a short term, fast maturing and nutrient demanding crop. The colour of stems and leaves of *Br. rapa* L. are green or light green, and yellow colour in flowers when anthesis occur. All the above grown plant tissues of *B. rapa* is commonly consumed. The optimum temperature suitable for cultivation of *B. rapa* is 23 – 35 °C and pH range 5.0 - 6.0. Adequate nutrient uptake during growth is critical, as it will greatly affect the yield and quality of *B. rapa*, thereby reducing the income of vegetable growers. The basic nutrient requirement for *B. rapa* in terms of macronutrient are N–78; P–9; K-158; Ca-49; Mg-9 measured in kg/ha (Aini *et al.*, 2005).

2.2 Organic fertilizer versus inorganic fertilizer

Organic fertilizers are proven of its ability to improve soil properties and enhance micro-flora in soil. Organic waste provides nitrogen source in a slow-releasing rate. It supplies the nutrient to crops and avoids losses of element through leaching as compared to chemical fertilizers. Studies on soil chemical changes using poultry manure fertilization showed substantial improvements in P, Ca and Mg levels in soil, compared to zero fertilizer and inorganic fertilizer treatments (Aini *et al.*, 2005). Pavlou *et al.* (2007) also suggest that the residual availability of N, P and K was enhanced in the soil receiving the organic fertilization. High residual availability of N, P and K may be obtained in the soil, following the sheep manure applications, which relates to manure dose; on the contrary no residual availability of N, P and K was obtained by inorganic fertilization applied via fertigation (Pavlou *et al.*, 2007). These studies have pointed out that the benefits of organic fertilization can bring towards the soil.

However, many controversies were found on the effect of organic fertilizer and inorganic fertilizers on the quality of crops, particularly in vegetables studies that showed different findings on effect of organic and inorganic fertilization on the yields and quality of vegetables. For example, a study on organically versus conventionally grown carrots and cabbage showed relatively few differences in the yield, and vitamins and mineral contents of the carrots and cabbages (Warman and Harvard, 1997). Another study about tomatoes grown in mineral fertilizer and chicken manure revealed that there was no significant difference in the yield, except the mean plant shoot biomass was higher in mineral nutrient solutions (Toor *et al.*, 2006). Meanwhile Liu *et al.* (2008) concluded that the applications of fertilizers had no effect on vitamin C levels in the plants. On the other hand, Warman and Harvard (1997) claimed that N content in conventionally grown carrot was higher although the difference was marginal in the yield, vitamins and mineral contents of carrots and cabbages. Another study on organic and inorganic fertilization on the effect on plant growth and nitrate content in lettuce leaves exhibited that high nitrate levels were observed in the inorganic fertilization treatments (Pavlou *et al.*, 2007). A study on yield and quality of greenhouse crops showed that the application of N and K fertilizers significantly increased the yields of kidney bean for first two years, but declined in the 3rd year (Liu *et al.*, 2008). The mean total ascorbic acid content of tomatoes grown using chicken manure was higher than the tomatoes grown with mineral nutrient solutions (Toor *et al.*, 2006).

2.3 Quality assessment

2.3.1 Growth parameters

Size and shape are attributes of major significance of *Brassica* crops. Size indirectly giving information to consumers how much the produce worth, it is also related to the weight. There are changes in the size of family units and rising dominance of single persons in present days, and it affects the size requirements for fresh vegetables in consumers controlled market. However, requirements or expectations for *B. rapa* are still preferably to be large in size and heavy in weight per head of vegetable. The shape is also another attribute which will indicate quality of vegetables. Although leafy vegetables cannot be perceived to have specific shape literally, the number of leaves exist on a single head can become an indicator to assess the quality of *B. rapa*.

2.3.2 Colour

Colour is an important factor in the rapid evaluation of the product quality and subsequent purchasing decisions (Dixon, 2007). Colour is the products of light reflected from the leaf surface. The consumers require an appearance of freshness which is associated with a green appearance. In *B. rapa* for example, the L* is the measures to determine the brightness on the foliage surface. It is known that the higher L* value indicates more degree of brightness on plants' surface. The a* measures the magnitude of colour from green (-a*) to red (a*) whereas the b* measure the magnitude of colour from blue (-b*) to yellow (b*). L* and a* together will reveal the foliage colour whether it is in dark green or light green colour, which indirectly provide information on the chlorophyll content in the plant foliage. On the other hand, the yellowing of the foliage is associated with senescence and not acceptable to retail customers. Senescence will cause the b* value continues to increase until yellow colour is visible on the foliage. Thus, evaluation of changes in colour using colorimeters can provide a rapid and non-destructive means of measuring post-harvest quality of the products (Huyskens-Keil, 2003).

2.3.3 Chlorophyll and carotenoids

The colour of the *B. rapa* is directly influenced by the presence of plant colour pigments. The colour is actually the result of the amount of selective light wave reflected in proportion to that absorbed by plant pigments. Pigments such as the green chlorophyll that are present in high quantities in most *B. rapa* contribute substantially to increase visual appeal. Chlorophyll is divided into chlorophyll a, chlorophyll b, these chlorophylls exist in large quantities in fresh and mature *B. rapa*, but will deteriorate as the plant tissues undergo senescence or deteriorate physiologically after harvest. Carotenoids also naturally exist in the foliage. The carotenoids content is more stable at the molecular stage; its deterioration rate is not as fast as chlorophyll, at least the initiation of deterioration is later than that of chlorophyll. Carotenoids is even found to increase in concentration in harvested produce, although its increment is trace and negligible. As the chlorophyll pigments begin to denature when the plants undergo senescence or during prolonged shelf life, carotenoids gradually show itself with yellow colour on the foliage surface, so it is the diminishing process of chlorophyll that cause carotenoids to be visible. This explains that *B. rapa* changes in colour from green to yellow as senescence occurs from the time the above ground tissues are separated from the roots.

2.3.4 Firmness

Firmness is the physical characteristics that can be sensed by the feeling of touch. Consumers are constantly making presumption on the quality by feeling the outer surface of vegetables. Sensing firmness or softness by hand is used as a guide to maturity and quality not only by consumers, but this practice is also done by experienced crop producers to decide the right time of harvesting. Texture can also be sensed by mouth to determine the chewiness, fibrousness, grittiness, mealiness, stickiness, oiliness or dryness. It is important for the retention of flavour appeal and crispness in *Brassica* crops which are cooked prior to consumption. The texture which only be evaluated by tasting are aspects of quality that cannot be controlled by the grower since they are very easily lost by over-cooking. The healthy eating lifestyle is changing the preference of consumers on *Brassica* vegetables. Increasingly, consumers are encouraged to consumed vegetables in the raw state, for example the uncooked salad style food, where the retention of crispness and flavour is of major importance. The texture of vegetables can generally be classified as firm or soft. The firmness is more important since softness indicates incipient enzyme-induced breakdown, resulting from over maturity or pathogen-related rotting. This attribute can be quantified by using standardized penetrometer tests that determine the rate at which needles pierce the produce when driven by a standard force. Compression can be determined numerically by exposing the produce to pressure imposed by a standard mass (Dixon, 2007). For *B. rapa*, since only the above ground tissues are consumed and it consists of stem (petiole) and foliage, different parameters need to be taken to evaluate the firmness of two separate physical parts. Stem of *Br. rapa* L. can be tested of its firmness by compression cutting mechanism, whereas the foliage can be tested by tension imposed on the leaves in attempt to find out how much force is needed to tear the tissues apart. Both parameters intimidate the biting mechanisms in the mouths.

2.3.5 Nutrient elements

There are all together sixteen essential elements that are required by plants for growth and physiological process. These elements include carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorous (P), potassium (K), calcium (Ca), magnesium (Mg), sulphur (S), boron (B), copper (Cu), iron (Fe), manganese (Mn), zinc (Zn) and chlorine (Cl). Besides C, H and O (non-mineral nutrient) which the plants can derive from the atmosphere and water, all other elements are further categorize into macronutrients and micronutrients depending on the amount needed by plants in the whole life cycle. Main macronutrients include N, P, K, Ca, Mg and S. Among them N, P and K are considered primary macronutrients whereas Ca, Mg and S are regarded as secondary macronutrients. Main micronutrients include B, Cu, Fe, Mn, Mo and Zn. They are needed by plants in minute quantities, but are as important as macronutrients; meanwhile micronutrients in large quantities are toxic to plants.

2.3.5.1 Nitrogen (N)

The nitrogen content in plant tissues is the most important attribute for producing higher yield of produce of vegetables. Plants absorb N as inorganic, mobile nitrate ions (NO_3^-), and in a few case as ammonium (NH_4^+) or amino (NH_2^+) ions. N plays a part in tetrapyrrole rings of chlorophyll which contribute to the green colour of leaf foliage, deficiency of N may cause the yellowing of leaves (Parker, 2000). It is also the major composition forming a wide variety of important nitrogen-containing metabolites including amino acids, storage proteins, catalytic proteins (enzymes) and nucleic acids, thus it not only help in plant growth but also benefits to human when consume food with adequate nitrogen content. However, nitrates are harmful to human although it is essential to plant health. Organic nitrogen occurs in manures, decomposing organic matter and urea. They must be oxidized before most plants can use it. Many plants deficient in nitrogen show pale green to yellow leaves, but each crop has its own characteristic symptoms. Nitrogen deficiency generally cause plant to grow slowly and restricts crop yield (McMahon *et al.*, 2002). The normal plant leaves contain N percentage range from 2.0 % to 5.0 % on dry weight basis. Excess N can cause bullish plants, where plants produce thick, leathery leaves that curl under dramatic fashion producing compact growth, especially during warm and sunny condition (Abdullah, 2010).

2.3.5.2 Phosphorous (P)

Phosphorous is required by plants in relatively large amount. P is very immobile in the soils and only moves primarily as soil particles are moved. P is absorbed mainly as orthophosphate ions ($H_2PO_4^-$) and to a lesser extent as monohydrogen phosphate (HPO_4^{2-}). P in normal mature leaves ranged from 0.2 to 0.5 % (Jones, 2003). P is a key element in the formation of AMP, ADP and ATP (adenosine mono-, di- and triphosphate), which play essential role in photosynthesis and respiration. P is a constituent of nucleic acid and phospholipids. In addition, adequate P also stimulates early crop maturity, increase roots proliferation and seed formation. Deficiencies result in stunted growth, accumulation of anthocyanin pigment and reduce yields of seed and fruits (McMahon *et al.*, 2002). Excess P in the root zone can result in reduced plant growth probably as a result of P retarding the uptake of Cu, Fe and Zn.

2.3.5.3 Potassium (K)

Besides N, potassium is the second largest amount of nutrient needed by plants for growth. K is absorbed by plants in its ionic form (K^+). It plays roles in regulating the opening and closing of stomata and in water retention. It promotes the growth of meristematic tissue (transported to young tissues rapidly), activates some enzymatic reactions, aids in nitrogen metabolism and the synthesis of proteins, and aids in carbohydrate metabolism and translocation but does not appear to be an integral part of plant constituents as do other nutrient elements (in protoplasm, fats or carbohydrates). K deficiency symptom will first appear in the leaves. It is also associated with weak stems, decrease yield, lack of disease resistance, and low crop quality. K is more mobile than phosphorous but less mobile than nitrates. It is readily leached from light sandy soils. K contents range from 1.5 to 4.0% for plant leaves and 6.0 to 8.0% for stem tissues (Jones, 2002). K can be made more available to plants when other cations are added to the soil, for example Ca^{++} added when the soil is limed (McMahon *et al.*, 2002).

2.3.5.4 Calcium (Ca)

Calcium is absorbed by the plant in the ionic form (Ca^{2+}) by passive mechanism. It is essential to all higher plants. The uptake of Ca mostly occurs in a region of the root just behind the root tip. Deficiency will first show by new growth, killing terminal buds in shoots and apical tips in roots, thus reducing plant growth (McMahon *et al.*, 2002). Ca movement in plants is related to transpiration, deficiencies can occur temporarily under unfavorable conditions. Adequate levels of Ca in mature leaves range from 0.5 to 1.5% (Jones, 2002). The uptake of Ca in plants can be affected by other ions such as NH_4, K and Mg (Abdullah, 2010).

2.3.5.5 Magnesium (Mg)

Magnesium is absorbed by the plant as an ion (Mg^{2+}). It is an essential nutrient, the central atom in the structure of the chlorophyll molecule. The magnesium salt of ATP is the chemical form of ATP that actually participates in hundreds of biochemical reactions in plant cells. Mg is mobile and can translocate from older to younger leaves. Its deficiency causes an intervenous chlorosis in older leaves (McMahon *et al.*, 2002). Mg in leaves is usually found in percentage ranged from 0.2 % to 0.8%. The absorption of Mg in plants is highly affected by competing ions such as NH_4, K, and Ca (Abdullah, 2010).

2.3.5.6 Boron (B)

The uptake and transport features of Boron is similar to Ca. B is not mobile in the plant. Only small amount of B are needed by plants (McMahon *et al.*, 2002). B deficiency affects the young growing buds, leaf tips and leaf margin, which leads to necrotic areas and chlorotic leaf tips. A normal leaf contains 20 ppm to 40 ppm of B. Excessive B from fertilizer solutions or from foliar sprays leads to toxicity (Abdullah, 2010).

2.3.5.7 Copper (Cu)

Copper is absorbed by plants in a small quantity. Cu deficiencies appear more frequently in highly organic soils but have been found in mineral soils in some countries. The amount of organic matter, soil pH and the presence of other metallic ions influence the availability of copper (McMahon *et al.*, 2002). Large quantities of copper in the soil can cause Fe deficiency, and strongly affect Zn uptake in plants. Cu is not highly mobile in plants but some Cu can be translocated from older leaves to newer leaves. Cu deficiency of young leaves cause chlorosis and elongation of the leaves. The normal level of Cu in plants ranges from 2 ppm to 20 ppm (Jones, 2002).

2.3.5.8 Iron (Fe)

Iron is more abundant in than other micronutrients, but often it is deficient because it is unavailable to plants because of its extremely low solubility. Plants may show chlorosis caused by Fe deficiency. Fe is not mobile, the deficiency appears first in the younger leaves as an intervenous yellowing that later progresses over the entire leaf; in severe cases the leaves become almost white. Fe is essential in photosynthetic processes and also functions in several enzymatic reactions. The plants can absorb Fe through its roots or leaves as either as Fe^{2+} or as a complex with organic salts (McMahon *et al.*, 2002). The range of Fe contents found in plant tissues is from 50 to 75 ppm (Jones, 2002).

2.3.5.9 Manganese (Mn)

Manganese is immobile in the plant and exists in the soil in several forms, depending on the soil environment. It is most available to plants if in the manganous state (Mn^{2+}, MnO) as an exchangeable cation in the soil. Mn deficiency can be caused by competition effect of other ions and symptom will first show intervenous chlorosis in the young leaves. Mn participates in photosynthesis, activation of enzymes, carbohydrate metabolism, and phosphorylation. Manganese may be applied as a foliar spray besides application as manganese sulfate ($MnSO_4$) to the soil (McMahon *et al.*, 2002). Foliar levels of Mn range from 10 to 200 ppm; the sufficiency range is from 10 to 50 ppm. Higher concentration can lead to toxicity in many crops (Abdullah, 2010). Excess of Mn in fertilizer reduce uptake of Fe.

2.3.5.10 Zinc (Zn)

Zinc is not highly mobile in plants. Soil characteristics influence zinc availability. Zn deficiencies have been observed in deciduous and citrus fruits, vegetables and field crops. Zn primarily acts as an enzyme activator in both animals and plants, and is important in human nutrition. Zn can be absorbed by the roots from the soil as the exchange cation (Zn^{2+}), or through the leaves when it is sprayed with $ZnSO_4$ solution or chelated compound. Deficiency symptoms first appear in the younger leaves as intervenous yellowing, followed by reduced shoot growth

(McMahon *et al.*, 2002). High concentration of Zn can lead to toxicity where the root growth is reduced, leaves are small and chlorotic. The sufficiency range for Zn in leaves is 15 to 50 ppm. While Zn is present throughout plants, it is preferentially retained by the root systems.

2.3.6 Macronutrients and micronutrients

There have been a large number of studies that attempt to investigate the difference between organically and conventionally grown food in terms of nutrient element composition. The types of studies and study designs varied considerably but majority of the studies had taken three main approaches, which is the chemical analysis of organic and conventional foods purchased from retailers, the effect of different fertilizer treatments on the nutritional quality of crops, and the analysis of organic and conventional foods produced on organically and conventionally managed farms.

The previous findings on nitrogen analysis on vegetables was quite convincing, major trends indicate that N level was predominantly higher from plants treated with inorganic or mineral fertilizers, compared to the organic fertilizer which is low in N source. Some common measures taken by researchers in the experiments were to determine N levels, protein content or nitrate concentration in the plant tissues. Among the parameters, nitrate was the most commonly assessed to show the effect and differences of organic and inorganic fertilizer treatments on plants. N was reported lower in organic fertilizer treatments in most of the previous studies as shown by Peavy and Greig (1972), Barker *et al.* (1975) and Kansal *et al.* (1981) after analyzed on N content in spinach. Clark *et al.* (1999) also showed that tomatoes treated with organic fertilizers were lower N level. Carrots treated with NPK fertilizers were higher in N compared to organic fertilizers according to Warman and havard (1997). Exception was found from Evers (1989) which showed carrots N content were similar in organic and inorganic fertilizer treatments. Besides N, other elements showed variation in results after subsequent treatments of organic and inorganic fertilizers.

Previous studies on analysis of nutritional values of grains, fruits and vegetables sourced from retailers, either of organic or conventionally grown origin, showed that the nutrient content in organic vegetables were generally higher compared to conventionally grown vegetables found in market. For instance, Anon (2000) in his paper entitled "Organic food is far more nutritious" claimed that the mineral levels of organic green bean, tomatoes, capsicum and silver beet were considerably higher. K contents were higher in organic carrots (Pither and Hall, 1990). Smith (1993) reported that organic apples had significantly higher levels of P, Ca, Mg, Fe and Mn while organic wheat had higher levels of P, K, Ca, Cu and Mn.

Studies on the nutritional values on food grown using different types of fertilizers have been carried out since 1970s. Generally, most research findings showed that organic fertilizers significantly improved the nutrients or mineral contents in food produce; otherwise, there were a number of findings showed no significant differences between both types of treatments. Findings supporting the benefit of inorganic or mineral fertilizers were less. Peavy and Greig (1972) showed P and Fe content from organic fertilizer treatments were higher compared to mineral fertilizer, whereas had little effect on K, Mg, Mn and Zn. Schuphan (1974) concluded in his 12 years research on many types of vegetables showing the effects of NPK fertilizer and compost had variable effects on the mineral contents (P, K, Ca, Mg, and Fe) found in vegetable. Svec *et al.* (1976) demonstrated that K content was higher for tomatoes under organic fertilizer treatment compared to mineral fertilizer, but other mineral contents such as P, Ca and Mg were reported no differences. Similar trend was reported by Nilsson (1979) where P and Ca were higher in organic fertilizer treatments but K and Mg were not affected in carrots, cabbages and leeks. Spinach grown in organic fertilizer was higher in Mn. However, the P, Cu and Fe content showed no trends towards any types of fertilizers (Kansal *et al.*, 1981). Lairon *et al.* (1984a) showed variable effects, but unclear trend from organic or mineral fertilizers treatments on the minerals content (P, K, Ca, Mg, Cu, Fe and Mn) of lettuce. Another paper of Lairon *et al.* (1984b) who studied on the same minerals after the effect of NPK fertilizer and organic fertilizer revealed there was no significant differences for leeks and carrots in pot trials; no significant differences for leeks and turnips in field trial; and in farm comparison the contents of K, Ca, Fe, Cu and Mn were not affected. However, P and Mg from organic fertilizer treatment in farm comparison were higher. Similar study by Termine *et al.* (1987) also stated no consistent trends were observed for mineral contents (K, Ca, Mg, Cu, Fe and Mn) of leeks and turnips. Evers (1989) mentioned that organic and inorganic fertilizer treatments had similar effect on N and Mg content, whereas content of P and Ca were higher in organic fertilizer treatments. The K content, however, was variable depending on the location where the carrots were grown. In an experiment on beetroot under organic and mineral fertilization, the Ca and Mg were reported similar on both treatments (Pfiffner *et al.*, 1993). Carrots and cabbage after treated with both organic and NPK fertilizers had some differences in minerals but not consistent over the three years study, except for B content which was higher in organic fertilizer treatments (Warman and Havard, 1997). In the following year the same researchers found that the P, K and Mg content was higher in organic fertilizer treatment (Warman and Havard, 1998).

There were many studies showed that the comparison of nutritional value of food produced from organic and conventional farms, the plants samples were collected directly from the farm. Generally, most research findings concluded that there were not many differences between the organically and conventionally grown crops. For example, Hansen (1981) compared the farm produce such as potatoes, carrots, beetroots and curly kale from two planting systems and found no major difference in terms of the macronutrients (N, P, K Ca and Mg). Leclerc *et al.* (1991) showed no differences in mineral content from carrots subjected to organic and conventional farming. Cayuela *et al.* (1997) found overall no differences in strawberries from organic and conventional farms. Clarke and Merrow (1997) also found similar results for the P, Ca, Mg, Fe and Zn in tomatoes. Recent study by Jorhem and Slanina (2000) in the quest to find out whether organic farming reduce the trace element contents in plant foods, they found no difference in Zn level between potatoes and carrots from organic and conventional farms. However, other researchers did find significant difference from certain crops. Leclerc *et al.* (1991) showed P was higher in organic celeriac. Pfeilsticker (1992) stated the biodynamic farming system produced overall higher mineral levels of K, Mg, Fe, Mn and Zn in vegetables. Weibel *et al.* (1999) showed that apples subjected to organic farming were higher in the P compared to conventional farming systems.

As the major trends concerning higher levels of nutrients point toward organic food purchased from retailers, food plants treated with organic fertilizers and organically grown crops from farm, there were few findings support the higher nutrient content in vegetables from chemical fertilization origins. Spinach treated with mineral fertilizer and mineral fertilizer with split N application was higher in the level of Ca (Peavy and Greig, 1972). Higher Zn level was observed spinach grown under urea treatment, a form of nitrogen-release fertilizer (Kansal *et al.*, 1981). Smith (1993) reported the Fe content was lower in organic wheat, which means higher in wheat subjected to chemical fertilization. Leclerc *et al.* (1991) reported Zn content was higher in conventionally grown celeriac. According to Pfiffner *et al.* (1993), K was higher in beetroot treated with mineral fertilizer compared with other organic fertilizers. K content was also significantly higher in lettuce subjected to mineral fertilizer treatment (Svec *et al.*, 1976). Furthermore, Warman and Havard (1997) reported carrots were higher in Mn and Cu after treated with NPK fertilizer.

2.4 Fertilizers

While plants can obtain nutrients from natural sources such as atmosphere, irrigation water, rainfall, and elemental nutrient from the soil, additional nutrient supplements are needed for sustainable crop production. Mineral nutrients are supplied to the soil by applying crop residues, animal manures, biofertilizers, chemical fertilizers, or natural occurring minerals.

2.4.1 Chicken manure

The excretion of chicken contains both solid and liquid parts and there is no urine loss. The decomposition rate of poultry manure is very weak. The fresh droppings contain 75 % N, 1.2 % P_2O^5 and 2 % K_2O. Study showed that poultry manure has direct and residual effect on rice and rice field in irrigated system (Sharma, 2002). Chicken manure not only contains better nutrients compared to other farmyard manure, but is also less voluminous than other organic source, thus helping in transportation from distant places. The cost of nutrients in chicken manure also appeared to be cheaper than other organic manures. Chicken manure is widely used by farmers as organic fertilizer in agriculture due to its availability as by-products of broiler and egg production. The chicken manure as compost is able to improve the soil especially for sandy and clay soils. It keeps the moisture and prevents leaching in sandy soil, and increase aeration and soil movement in the clay soil. The chicken manure is high in pH value and nitrogen but low in organic carbon and carbon to nitrogen ratio. The chemical properties of chicken manure may less satisfy the nutrient requirement of certain crops such as potato, wheat and sugar beets. Toor *et al.* (2006) demonstrated that the slow-release of nutrients from the chicken manure caused slow growth of plants, however there was no significant differences in weights of tomatoes harvested compared to other inorganic fertilizers.

2.4.2 Vermicompost

Vermicompost is the digested excreta of earthworms from eaten biomass, it is a stable fine granular organic matter, when added to clay soil loosens the soil and provides the passage for the entry of air. The mucus associated with the cast being hygroscopic absorbs water and prevents water logging and improves water holding capacity. Thus, in the sandy soil where there is the problem of water retention, the strong mucus coated aggregates of vermicompost hold water for longer time. The commonly used composting materials are of biologically degradable and decomposable organic wastes such as animal manure and agricultural waste (Sharma, 2002).

In vermicompost, some of the secretions of earthworms and the associated microbes act as growth promoters along with other nutrients. It improves physical, chemical and biological properties of soil in the long run on repeated application. The organic carbon in vermicompost provides additional substances that are not found in the chemicals (Sharma, 2002).

Vermicompost affect the growth and yield of crops in many positive ways. Vermicompost contain macronutrients and micronutrients in their secretions and excreta in considerable quantities. Certain metabolites produced by earthworms may also be responsible to stimulate plant growth. Although the NPK value of the vermicompost is always lower than any standard chemical fertilizer, several experiments have proved that vermicompost can promote lush growth of plants. The main reason is due to the presence of plant growth hormones such as auxins and cytokinins present in the vermicompost. Earthworms are also considered to release certain vitamins and similar substances into the soil (Sharma, 2002).

Substitution of NPK fertilizer with vermicompost (7.5 tan/ha) drastically reduced the incidence of physiological disorders in strawberry indicating that vermicompost had significant role in reducing nutrient-related disorders and disease like Botrytis rot, and thereby increasing the marketable fruit yield up to 58.6% with better quality parameters. Fruit harvested from plant receiving vermicompost were firmer, have higher TSS, ascorbic acid content and lower acidity, and have attractive colour. Antonio *et al.* (2008) showed that vermicompost leachate can be used as liquid fertilizer for the cultivation of sorghum, because the vermicompost leachate stimulated plant development. Apart from micronutrients, vermicompost leachate also contains humic and fulvic acids that promote growth of sorghum plants. However, the study showed maximum growth of the plants was achieved with combination between vermicompost and NPK fertilizer. On the other hand, Muhammad *et al.* (2007) found poor growth, low leaf chlorophyll content and depressed N content, only zinc showed increase when evaluating the growth characteristic of lettuce subjected to pure vermicompost treatment. Zaller (2007) showed the marketable and total yields of field tomatoes were not affected by different vermicompost amendments rates. However, morphological (circumference, dry matter content, peel firmness) and chemical fruit parameters (contents of C, N, P, K, Ca, Mg, L-ascorbic acid, glucose, fructose) were significantly affected by vermicompost amendments specific in different tomato variety.

2.4.3 Biofertilizer

Biofertilizers are microbial inoculants or organic materials converted by microbial activities which are used to provide nutrients to plants. Microbial inoculants include *Rhizobium* and *Azospirillum*, phosphate-solubilizing bacteria, *mycorrhizal* fungi, and cyanobacteria, or plant-algae symbioses.

Biofertilizers are capable of mobilizing nutritive elements from non-usable form through biological process. Microorganisms induce many biochemical transformations in the soil. These include mineralization of organically bound forms of nutrients, exchange reactions, fixation of atmospheric nitrogen and various other changes leading to better availability of nutrients already present in the soil (Sharma, 2002).

Biofertilizers are not completely fertilizers in nature; they do not contain substantial quantity of plant nutrients as other fertilizers like urea, diammonium phosphate or muriate of potash. The term biofertilizers is a misnomer but is in wider use. They should be termed as inoculants, after the name of microorganisms they contain, such as *Rhizobium* innoculant, *Azospirillum* inoculants or blue green algae inoculants. Biofertilizers are different from chemical fertilizers. Biofertilizers on application remain in soils, multiply and keep benefiting the growing crops. They do not get depleted as in the case of fertilizers and therefore if the optimum soil conditions prevail, population of added microorganisms builds up and thus avoiding frequent application of biofertilizers. Organisms used for biological fertilizer management are either free living or having symbiotic association with plants. They directly or indirectly contribute nutrition to crop plants, available for almost all crops and high in three nutrients, which are nitrogen, phosphorous and zinc (Sharma, 2002).

Biofertilizers often are referred as microbial fertilizer that exists in liquid or powder form. It can be applied to seeds, plants, soil, or decomposition products. It increases soil nutrients and improves the efficient of nutrition uptake by plants. Modes of application are either by foliar spraying or incorporated into the irrigation water.

Plant growth promoting rhizobacteria can affect plant growth by production and release of secondary metabolites (plant growth regulators, phytohormones and biologically active substances), lessening or preventing deleterious effects of phytopathogenic organisms in the rhizosphere and facilitate the availability and uptake of certain nutrients from the root environment. Foliar application of biofertilizer (*Azatobactor chroococcum*) is better than soil application. Both biochemical and morphological characters showed significant level of improvement when biofertilizer was sprayed on the leaves of mulberry. Plants treated with biofertilizer had more leaf pigments compared to chemical fertilizer treated plants.

2.4.4 Inorganic fertilizer

Inorganic fertilizer, also referred as chemical fertilizer or mineral fertilizer, is a type of fertilizer that is highly commercialized and used in intensive crop cultivation. There are two kinds of inorganic fertilizers, which are the single fertilizer and complete fertilizer. Single fertilizers contains only one or two nutrient source, whereas the complete fertilizers contains two or more nutrient elements that are mixed together, the example is NPK compound fertilizer. A complete fertilizer contains the three primary nutrients: nitrogen, phosphorous and potassium, besides secondary macronutrients, if applicable. Each bag of commercial fertilizer carries a label stating the analysis of its contents. For instance, in the figures 15-15-15, the first figure is the percentage nitrogen by weight (15 kg nitrogen per 100 kg of fertilizer). Subsequent figures are the percentage of phosphorous and potassium respectively. The remaining weight consists of other chemicals in the formulation or of filler. Some commercial fertilizer also stated additional composition of trace elements (TE) after figures shown by NPK, which indicates the presence of certain amount of micronutrients. While label on the bag states the percentage of each primary nutrient, it may not indicate the compounds used to make up the fertilizer. Nitrogen in the fertilizer might be supplied as urea, ammonium nitrate, ammonium sulphate, or sodium sulphate and so on. The primary source of phosphorous is mined apatite (rock phosphate), superphosphate, liquid phosphoric acid (H_3PO_4), ammonium phosphate, and basic slag (a by-product of steel industry). The most widely used potassium fertilizers are potassium chloride (KCl), potassium sulphate (K_2SO_4), and potassium nitrate (KNO_3), commonly known as muriate of potash, sulphate of potash and salt peter, respectively (McMahon *et al.*, 2002). The formulation is important because it informs the user of what compounds are used and their chemical form. It also indicates the fertilizer's nutrient availability, effect on soil pH and ease of incorporating into the soil.

CHAPTER 3

METHODOLOGY

3.1 Location

Brassica rapa cultivation was conducted at a shade house with transparent roof and black netting placed at each side of the shade house at temperature 29±4°C with light intensity ranging from 600 to 1000 $\mu mol s^{-1} m^{-2}$. *Brassica rapa* quality assessment was carried out in Postharvest Technology Laboratory, Universiti Malaysia Terengganu (UMT).

3.2 Plant materials

Brassica rapa seeds were purchased from LECKAT CORPORATION SDN. BHD. Product named Green World Vegetable Seeds (Pak Choy)

3.3 Types of fertilizers

Four different types of fertilizer were used in this study as shown in Table 3.1

Table 3.1: Organic and chemical fertilizers from different companies.

Fertilizer sources
Inorganic compound fertilizer Company: BEHN MEYER & CO. (M) SDN. BHD. Product: Nitrophoska 15–15-15-2
Chicken manure & compost Company: ZENXIN AGRICULTURE SDN. BHD. Product: Midori Pure Active Organic Fertilizer
Vermicompost Company: GREEN ECO BIOTECH SDN. BHD.
Organic foliar fertilizer Company: WELLGROWTH BIOTECH SDN. BHD. Product: Max Growth Foliar Biofertilizer

(Refer Appendix C for nutrient composition in fertilizers.)

3.4 Experimental setup

Brassica rapa seeds were germinated in 35 x 25 cm trays using commercial potting mix soil. When the plants reached 3-4 leaf stage, each seedling was transplanted into pots (12 cm diameter x 7 cm high) containing sandy loam soil with a pH 5.7. Plants were watered twice per day throughout the whole cultivation period. Different kinds of fertilizers were applied at recommended rates and frequency with modification according to Department of Agriculture (1998). For foliar biofertilizer, application was done based on the concentration recommended by the company (Table 3.2). The plants were harvested 30 days after transplant. Quality assessment was conducted immediately.

Table 3.2: Application of fertilizers with specific rate, mode, and frequency.

Treatments	Application rate	Application mode	Application frequency
Control	Nil	Nil	Nil
Chicken manure & compost	5 t/ha/season	Band	One week before transplant, 1st and 2nd week
Vermicompost	5 t/ha/season	Band	One week before transplant, 1st and 2nd week
Organic foliar biofertilizer	1:500 fertilizer to water ratio	Sprayed on foliage and soil	Every week after transplant
Inorganic compound fertilizer	0.6 t/ha/season	Band	One week before transplant, 1st and 2nd week

3.5 Quality assessment

3.5.1 Growth parameter

Growth parameters were used to test the physical attributes of each *B. rapa* plant. The data were collected in terms of edible leaf number per plant, plant fresh weight, leaf area and visual quality after harvest. Fresh weight of each plant was measured with top pan balance. Leaf area of each plant was measured using the leaf area meter CI-202. For visual quality, the plants were assessed by using a 9-point category scale as shown in Table 3.3.

Table 3.3: Visual score of vegetables (Fan and Sokorai, 2008).

Score	Quality description
9	excellent quality, essentially free from defects, fresh appearing
7	good quality, minor defects
5	fair quality, slightly to moderately objectionable defects, lower limit of sale appeal
3	poor quality, excessive defects
1	extremely poor quality, not usable

3.5.2 Leaf color

The leaf color was determined with a chromameter (Minolta CR-300, Osaka, Japan) based on the Commision Internationale de L'Eclairage (CIE) LAB colour space system where L* measures the degree of lightness, a* from green to red and b* from blue to yellow.

3.5.3 Chlorophylls and carotenoids

The chlorophylls and carotenoids contents present in the leaves were determined by amount of absorption of each leaf pigment extract using a UV-Vis spectrophotometer at a specific wavelength. The concentration was calculated using equations as shown in Table 3.4.

Table 3.4: Leaf pigment wavelengths and equation to calculate the concentration of pigments (UMT Department of Agrotechnology, 2008).

Type of leaf pigment	Wavelength (nm)	Concentration of leaf pigment (μg/ml)
Chlorophyll a	662	$(11.24\times Abs_{662}) - (2.04\times Abs_{645})$
Chlorophyll b	645	$(20.13\times Abs_{645}) - (4.19\times Abs_{662})$
Carotenoids	470	$[(1000\times Abs_{470}) - (1.90\times Chl\ a) - (63.14\times Chl\ b)]/214$

3.5.4 Firmness

The firmness of *B. rapa* leaves and stems were determined with a Stable Macro System, TA-XT Plus texture analyzer. The stem (petiole) firmness was quantified by using standardized blade tests that determine the rate at which blade pierce the stem at compression mode. The leaf firmness was measured with tension mode; leaves are cut into uniform rectangular shape (4.0cmx1.5cm), avoided leaf veins and a notch was made at the middle of the cut leaves. The two ends of the cut leaves were sticked to a modified probe to test the force needed to tear the leaves. The assessment of firmness was expressed in force (g).

3.5.5 Nutrient content analysis

3.5.5.1 Nitrogen contents

Kjeldahl method was conducted, which involved digestion, distillation and titration steps. 0.1 gram of homogenised dry leaf powder was put into 50 ml Kjeldahl flask and mixed with 1.0 gram of Kjeldahl catalyst and 5 ml of concentrated sulphuric acid. The mixture was mixed thoroughly and left for 30 minutes, then the mixture was heated in a fume hood until it became clear and digestion was continued for another 45 minutes. Then, the mixture was left to cool down and the flask wall was washed with little distilled water. The mixture was shaken in Kjeldahl flask, then the Kjeldahl flask was washed a few times with as little distilled water as possible and the washed mixture was filled into the distillation flask. 12 ml 30% NaOH was inserted into the mixture. The ammonia gas that was released into a conical flask (which already contains 5 ml 3% acid boric and mixture indicator material) was collected. The acid boric solution was titrated with 0.01M HCL to determine the percentage of nitrogen present in the plants (Ahmad *et al.*, 1990).

3.5.5.2 Potassium, calcium, magnesium and micronutrient contents

Dry ashing method was used. 2 gram of homogenised plant tissue was transferred into a ceramic bowl and put into 'muffle furnace'. The bowl was heated gradually until the temperature reached 300°C and this temperature was maintained until the smoking cease. The temperature was raised again to 500°C and this temperature was maintained until white/grey ash appears. The bowl was taken out and let it cool. Distilled water was added to the ash, followed by 2 ml concentrated HCL. The mixture was vaporized in a heater saucer. 10 ml acid nitric was added to digest the ash for 1 hour. Next, the digested mixture was inserted into a 100 ml volumetric flask. The bowl was washed a few times to make sure all digested mixture was transferred into the volumetric flask. Then distilled water was added to make up to 100 ml solution. The mixture was mixed thoroughly and filtered with No. 2 filter paper. Finally, plant tissues in extraction were tested using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). The data were obtained in ppm and the concentration of K, Ca and Mg were converted to percentage per plant (Ahmad *et al.*, 1990).

3.5.5.3 Phosphorous contents

Yellow molybdate method was conducted. 3 ml of the plant extract solution from dry ashing method (as described in 3.5.1.2) was mixed with 25 ml ammonium molybdate/ammonium vanadate solution. The amount of absorption was determined after half an hour using a UV-Vis spectrophotometer at a wavelength of 410 nm. The concentration of phosphorous in ppm was determined from a standard curve in accordance to phosphate standard solution ranged from 0 to 80 ppm. The data were converted in phosphorous percentage per plant (Ahmad *et al.*, 1990).

3.6 Statistical analysis

The experiment was conducted in a complete randomized design with five replicates. All data were checked using SPSS for normality and homogeneity of variance. 1/X transformation was performed on data of plant Manganese contents in, log (1+X) was performed on data of fresh weight, plant phosphorous and iron contents, square root transformation was performed on data of plant nitrogen, boron, calcium and magnesium contents before being subjected to one way ANOVA, and the means was separated using Tukey Test at 5% of significant level ($P<0.05$).

CHAPTER 4

RESULT AND DISCUSSION

4.1 Number of Edible Leaves

The number of leaves produced by *Brassica rapa* subjected to different types of fertilizers is shown in Figure 4.1A. The amounts of leaves were recorded at the harvesting time, which is 4th week of the experiment. The maximum numbers of leaves formed were recorded approximately 6, 13, 11, 8 and 23 when being treated with control (CTL), chicken manure (CKN), vermicompost (VER), foliar biofertilizer (FOL) and chemical fertilizer (CHE) respectively. Analysis of variance (ANOVA) showed that there was a significant difference ($p<0.05$) in the leaf number among different types of fertilizers. The post-hoc Tukey's test indicated that CHE produced the highest number of leaves as compared to plants applied with other treatments. CKN and VER were similar in terms of in promoting greater number of edible leaves while FOL was not significantly different from the control. Toor *et al.* (2006) reported a similar trend for the tomatoes grown with mineral nutrient solution, with the crops having higher shoot biomass compared to those treated with chicken manure and grass-clover mulch.

4.2 Fresh weight

The harvested shoot fresh weight of *Brassica rapa* after being treated with different types of fertilizers is shown in Figure 4.1B. There was a significant difference in the fresh weight among different fertilizer treatments ($p<0.05$). Plants treated with CHE were significantly higher in weight, meanwhile other treatments on the plants were also not analogous in their performance towards plant growth in weight; CKN>VER>FOL>CTL. This result was in line with the finding of Saidou *et al.* (2003) that showed NPK fertilizer can increase maize yield compared to sole mulch treatment. The yield can be regarded as fresh weight as most plants or produce from plants are measured of its weights to represent total yield. In another experiment, the combined fertilization of N, P_2O_5 and K_2O was found to be effective on enhancing yield and all quality properties of tomatoes (Doran *et al.*, 2007). Liu *et al.* (2008) indicated the application of N and K fertilizer increased the yield of kidney bean for the first and second year.

However, an early study by Lairon *et al.* (1984a) on the effect of organic and mineral nitrogen fertilization reported equivalent yield of butterhead lettuce. Similarly, Toor *et al.* (2006) demonstrated that no significant difference in the yield of tomatoes treated with organic and mineral fertilizers. An earlier research on organically and conventionally grown carrots and cabbage showed the yields of plants were not affected by compost and NPK fertilizer (Warman and Havard, 1997). A research carried out in Kenya reported that sole manure and sole nitrogen fertilizer had identical effect on the yield of maize (Mucheru-Muna *et al.*, 2007). Another field research was conducted on seven cropping seasons by Blatt (1991), comparing several

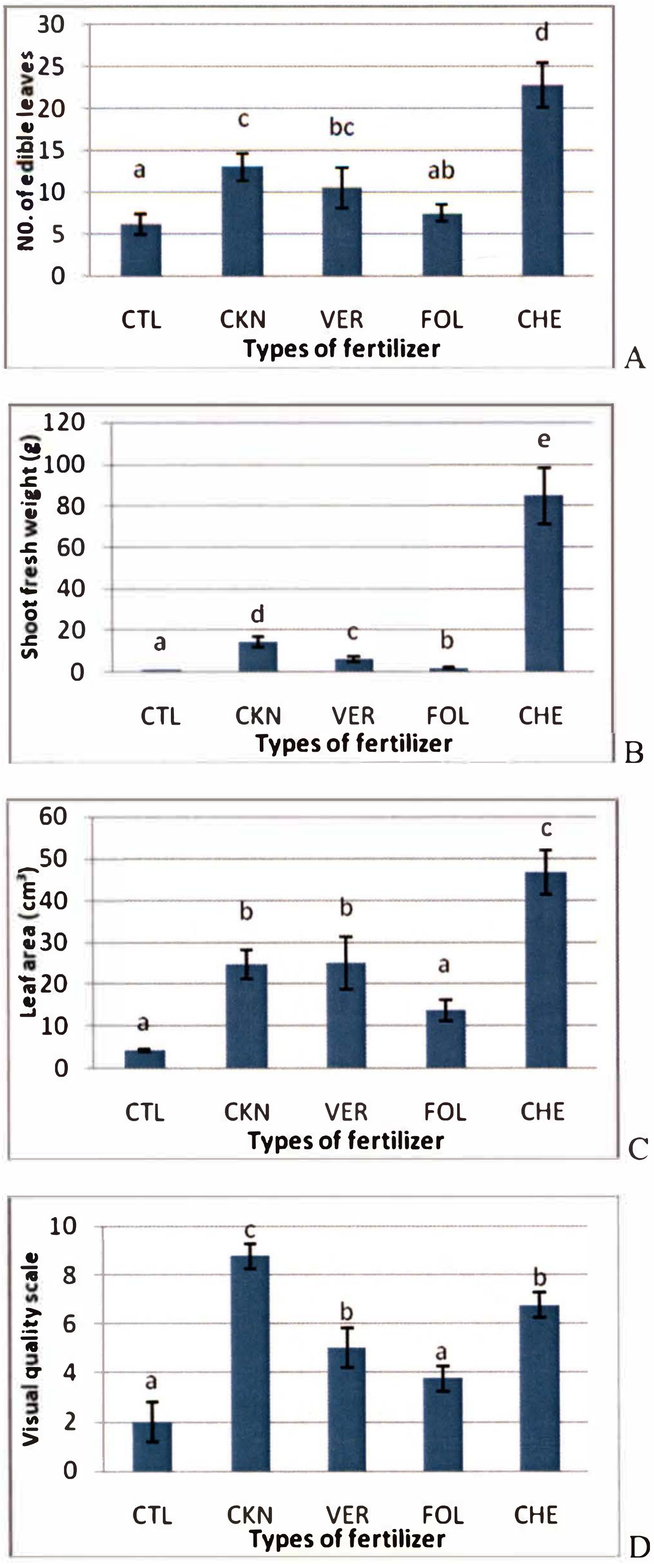

Figure 4.1: Effect of chicken manure (CKN), vermicompost (VER), foliar biofertilizer (FOL), chemical fertilizer (CHE) and control (CTL) on the number of edible leaves (A), fresh weight (B) and leaf area (C) and visual quality (D) for *Brassica rapa* (L.) after four weeks of fertilization. Vertical bar represent standard deviation (SD) of mean. Treatment with the same letter denotes no significant difference at $P<0.05$.

organic amendments with chemical fertilizer (17-17-17) applied to seeded beans, carrots, peas, sweet corns, transplanted broccoli, Brussels sprouts, cabbage, cauliflower and lettuce. It showed that the plants receiving organic amendments in majority cropping seasons had comparable yield and size to those from plants receiving the chemical fertilizer treatment.

4.3 Leaf area

The effects of different fertilizers types on leaf area of *Brassica rapa* are shown in Figure 4.1C. It is indicated that leaf area was significantly different among all treatments ($p<0.05$). Plants treated with CHE exhibited the highest value of leaf area (Appendix A), whereas CKN and VER had similar effect on leaf area. Meanwhile, FOL did not help in enhancing plant growth with larger leaf area.

A significant correlation emerged from assessing the growth parameters; number of edible leaves, fresh weight and leaf area are correlated according to treatments. CHE gave significantly higher value in all the three parameters. The plants treated with chemical fertilizer had advantages over other fertilizer types in fresh weight, leaf area and number of edible leaves. These results are in agreement with the findings of Wang *et al.* (2007), the effect of NPK fertilizater on nutritional quality of cereal, oilseed, protein crops, tuber plants and vegetables increases the crop yield. In contrast, there was a controversial finding of Stamatiadis *et al.* (1990), where differences between compost and N fertilizer treatments in crop yield and number of broccoli heads were insignificant and relatively small.

On the other hand, FOL performed poorly on the all of the growth parameters; it did not have significantly higher value in tested growth parameters as compared to control except for fresh weight. The result has posted a different verdict from Stancheva *et al.* (2004) that revealed favourable effect of foliar fertilizer on the biomass accumulation in various vegetative organs of garden beans. Higher value of fresh biomass, leaves, stems and roots are observed with application of foliar fertilizer at budding and flowering stages of the garden beans. The positive result of foliar fertilization on crops by Stancheva *et al.* (2004) may be due to the presence of high nutrient level (N:P:K = 20:20:20) and all important microelements. Comparatively, the poor performance in FOL did not provide much of those nutrients. The formulation of biofertilizer is focusing on beneficial microorganisms which can enhance the soil properties and symbiotic effect of microbes and plants at the same time. The nutrient contents in FOL was not as high as other fertilizers.

VER have not performed well in promoting the growth of *B. rapa* (Figure 4.1A, B, C). The N, P, and K contents in proved that VER is less competent compared to CKN and CHE in promoting plants growth (Appendix B). The present finding was supported by Muhammad *et al.* (2007) that demonstrated that poor growth was observed in lettuce subjected to pure vermicompost fertilization. Zaller (2007) also reported that the marketable and total yields of tomatoes was unaffected by different rates of vermicompost treatment. However, the average leaf area of VER treated plants was higher than CKN. This may be due to the effect of plant growth hormones such as auxins and cytokinins that caused the enlargement of plant cells from the leaves for VER treated plants.

The results of present study suggest that *B. rapa* did not obtain adequate nutrients for growth when treated with VER and FOL. In addition, the plants did not benefit much from the phytohormones provided by VER and FOL that are supposed to enhance the plant growth, as compared to the chemical fertilization of CHE. However, the application of VER and FOL did help in reducing disease or physiological disorder with introduction of beneficial microbial inoculums, as all plants treated with VER and FOL were healthy until harvested. The finding was supported by Sharma (2002).

Chicken manure appears to be the best organic fertilizer among the three. The higher N, P and K contents in the granule form fertilizer has contributed to the maximum growth of plants compared to other organic fertilizers. However, in terms of edible leaf number and leaf area of plants, it was not significantly different from vermicompost ($p>0.05$). Although there are many controversies in the previous studies, the overall yields of crops were very much dependent on the soil type, climate in particular cropping season, species and cultivars of the crops. In the present study on *B. rapa*, it clearly shows that chemical fertilizer treatment is better in all three growth parameters, in comparison with other organic fertilizers when being applied on *B. rapa*.

4.4 Visual quality

Evaluation of the quality of plants was also done based on visual assessment. The evaluation was conducted using a 9-point category scale according to Fan and Sokorai (2008). CKN-treated plants had significantly better visual quality compared to plants treated with other fertilizers (Figure 4.1D), the results indicate that CKN-treated plants had fresh appearance, very good quality and free from defects. VER and CHE treated plants were second ranked, with fair quality and minor defects in terms of colour and shape respectively. FOL-treated plants had poor quality especially on the leaf edge area.

4.5 Lightness (L*), chromaticity value a*, b*

In vegetable, the colour and gloss contribute to the visual appeal towards quality. Gloss is the result of light detected after reflected from the leaf surface. The L* value ranged from 0 (black) to 100 (white), the higher the L* value, the brighter the colour would be. The CHE treated plants had the lowest L* value (Figure 4.2), indicating the darkest colour was observed from the leaves. CKN and VER brought analogous effect on the leaf lightness. FOL treated plants and CTL exhibited the highest L* value. The results indicate that FOL affects the glossy characteristic of the plant leaves more than other treatments. CHE treatment did not contribute to the glossiness of the leaf surface. FOL may have caused the plants to have a natural waxy layer over the leaves surface, CKN and VER treatment also contributed in this characteristic but to a lesser extent. The waxy layer acts as a protective layer on *B. rapa* may help to lengthen the shelf lives of the produce after harvest.

The a* value was observed not significantly different among treatments, except less negative a* value for CHE treated plants. It is found that CHE treated plants had a lower degree of green colour (pale green) compared plants treated with

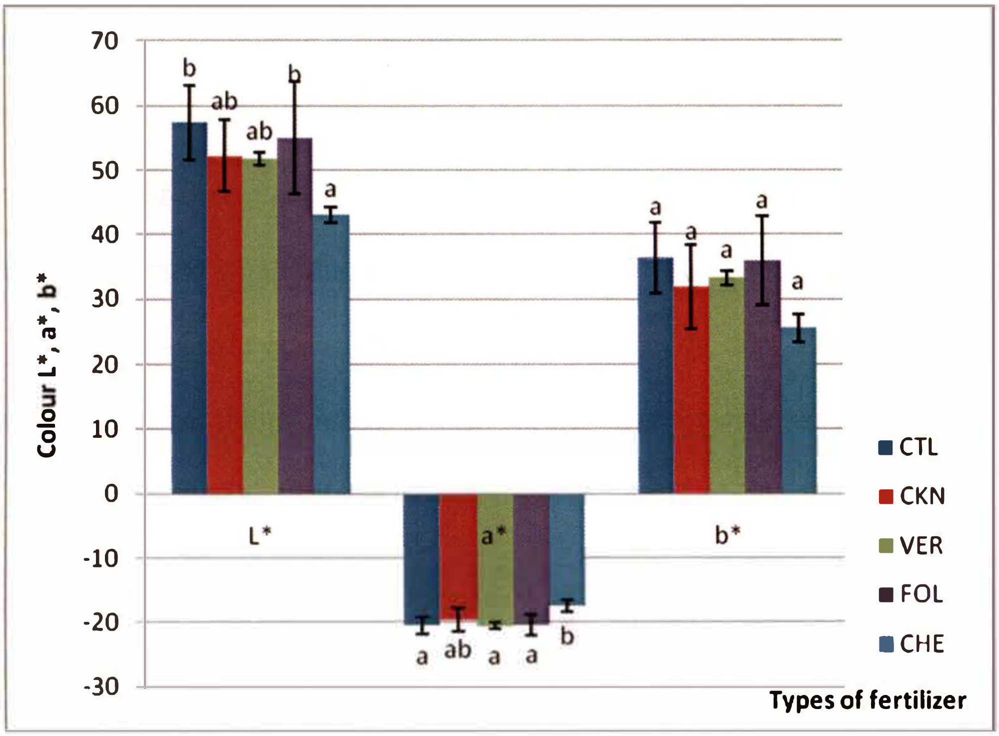

Figure 4.2: Effect of chicken manure (CKN), vermicompost (VER), foliar biofertilizer (FOL), chemical fertilizer (CHE) and control (CTL) on the L*, a* and b* for *Brassica rapa* (L.) after four weeks of fertilization. Vertical bar represent standard deviation (SD) of mean. Treatment with the same letter denotes no significant difference at P<0.05.

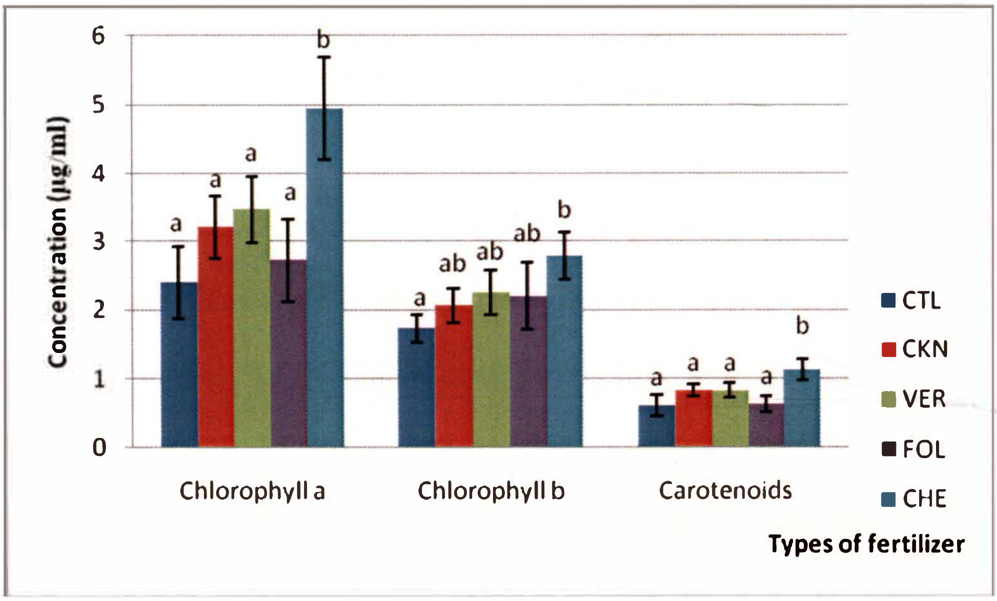

Figure 4.3: Effect of chicken manure (CKN), vermicompost (VER), foliar biofertilizer (FOL), chemical fertilizer (CHE) and control (CTL) on the chlorophyll a, chlorophyll b and carotenoids content for *Brassica rapa* (L.) after 4 weeks of fertilization. Vertical bar represent standard deviation (SD) of mean. Treatment with the same letter denotes no significant difference at P<0.05.

other treatments. Meanwhile CKN treated plants was different from other organic fertilizer treatments and CTL although the difference in a* value was not significant (Figure 4.2). Schreiner *et al.* (2003) showed that changes to colour corresponded to post-harvest changes of soluble and insoluble pectin substances, total glucosinolates and alkenyl glucosinulates in reddish. The present study may show higher soluble pectin and lower insoluble pectin in organic fertilizer treatments, correspond to the more negative value of a* of those treatments.

Meanwhile b* was not significantly different among all the treatments. It implies that all the treatments were in proper physiological stage during harvest and no senescence or yellowing occurs which can lead to higher b* value.

4.6 Chlorophyll and carotenoid

Figure 4.3 shows the chlorophyll a, chlorophyll b and carotenoid contents found in the plant tissues. CHE treated plants had the highest chlorophyll a content (Figure 4.3). It implies that the high N composition from inorganic fertilizers supply N in high percentage to build tetrapyrrole rings of chlorophyll, which contributed to the green colour of leaf foliage. VER and CKN treated plants were higher in chlophyll a compared to FOL treated plants, although the differences are not significant. Interestingly, VER with lesser N percentage cause higher chlorophyll a concentration compared to higher N percentage from CKN. Interestingly, CKN treatment resulted in lower chlorophyll b concentration than FOL, though the difference was not significant

(Figure 4.3).

Carotenoids contents of treated plants exhibited the same pattern as shown in the content of chlorophyll a. Chemical fertilizer treated plants had 1.13 μg/ml of carotenoids while other organic fertilizers had carotenoids content less than 1.00 μg/ml levels. The present finding of this study is not in agreement with most of the previous studies in the levels of carotene as affected by different fertilizer treatments. For instance, Schuphan (1974), Nilsson (1979), Lieblen (1993) Warman & Havard (1997), and Anon (2000) found relatively small differences or insignificant differences in carotene concentration between different organic and chemical fertilized crops. Surprisingly, the results of plant colour pigments did not correspond to the a* and b* value. Normally, high a* value of plant leaves supposed to indicate higher chlorophyll a, similarly high b* value of plant leaves supposed to reflect higher chlorophyll b and carotenoids in plants. It is most likely that the lower pigment concentrations of organic fertilizer treated plants were detected as a result of masking of other compounds in extracts or variation occurred during sample analysis.

4.7 Firmness

Figure 4.4 shows the leaf and stem firmness of *Brassica rapa* with an interesting finding. The result indicates that leaves of CKN treated plants had higher firmness value. Surprisingly, CTL treated plants had even a better firmness of leaves compared to plants treated with VER, FOL and CHE (Figure 4.4). CKN treatment may have resulted in thickening of collenchymas tissues in leaves, thereby increasing the mechanical strength of cell walls and decreasing water content in plant tissues. A previous study by Schuphan (1974) has shown that organically grown plants have a more solid collenchymatous thickening system, thus increasing the mechanical strength of cell walls and a decreased water content in plants tissues which both favouring a protective effect against aphids. This may explain leaves of CKN-treated plants have more firm leaves as compared to the soft and fragile CHE-treated plant leaves.

On the other hand, the stem firmness of CHE-treated plants had significantly higher value while CKN and VER were better than FOL in attaining firmer leaves and stems (Figure 4.4). These results are not suitable to represent the actual differences between plants subjected to organic and chemical fertilizer treatments. This is because the CHE treated plants were very much greater physically in terms of weight and size, thus the conducted experiment on stem firmness could not demonstrate the relative difference. There was similar effect on stem firmness between CKN and VER treatments although VER treatment did not enhance sufficient growth towards plants as compared to CKN. Nevertheless, higher stem firmness does not necessary mean better quality of *B. rapa*. Instead, extremely firm *B. rapa* stem is associated with hardening that give unfavorable eating attribute.

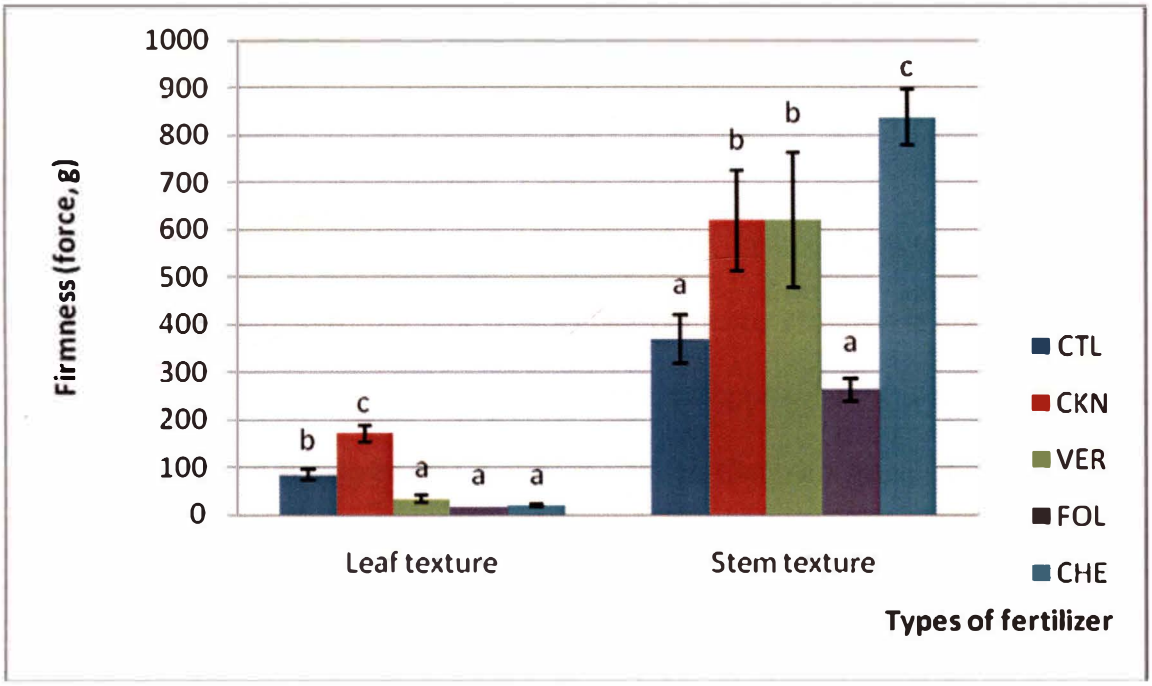

Figure 4.4: Effect of chicken manure (CKN), vermicompost (VER), foliar biofertilizer (FOL), chemical fertilizer (CHE) and control (CTL) on the leaf texture and stem texture for *Brassica rapa* (L.) after four weeks of fertilization. Vertical bar represent standard deviation (SD) of mean. Treatment with the same letter denotes no significant difference at $P<0.05$.

4.8 Macronutrients

The present data have presented a different perception about the effect of organic and inorganic fertilizers on vegetables from many previous studies (Peavy and Greig 1972, Barker 1975, Kansal *et al.* 1981), as opposed to the more favourable results towards organic vegetables. Figure 4.5 shows that plants treated with CHE had significantly higher percentage in all of the macronutrients including N, P, K, Ca and Mg. This finding is supported by Peavy and Greig (1972), Barker (1975) and Kansal *et al.* (1981) stated that the N content was lower in organic (particularly manure) fertilized spinach. Furthermore, Clark *et al.* (1999) stated that the N content was significantly higher in tomatoes while Warman and Havard (1997) also found higher N content in carrots; both crops planted in conventional planting system where chemical fertilizer was used. Most of the previous studies had demonstrated that higher N percentage when the crops were treated by chemical fertilizer. Interestingly, both VER and FOL-treated plants had N percentage even lower than CTL plants which were not treated with fertilizer (Figure 4.5A).

Nitrogen exists as free nitrate in vacuole sap. It accumulates at in conductive tissues (petioles and stems) during vegetative growth, primarily at the bases of the stems and in petioles of matured leaves. In the present study, dried above ground tissue of *B. rapa* were homogenised to obtain N content of each treatment accurately. In general, N contents in plants ranged from 1.0 to 6.0% of dry weight in leaf tissues (Jones, 2002). The results of this study show that only plants treated with CKN or CHE had N contents that fall into the range (Appendix B), with the data corresponding with CHE-treated plants that had higher concentration in chlorophyll a and b contents (Figure 4.5A).

Meanwhile VER and FOL supplied low N content to the plants (Figure 4.5A), thereby resulting in slow and stunted growth (Figure 4.1A, B, C). Surprisingly, the finding of this study shows that VER and FOL treated plants had N content even lower than CTL. It is most likely that the microorganisms from VER and FOL had used up the N content from soil, thus causing deficient uptake by plants. On the other hand, CHE showed N toxicity symptoms as epinasty was identified in CHE treated plants due to extremely high N content in chemical fertilizer (Appendix B). This result corresponds to the visual quality of CHE treated plants which were found to have objectionable defects (Figure 4.1D). This was unexpected because CHE was applied based on the recommended rate for vegetable cultivation. It is likely that ammonium cannot be incorporated into carbon containing N compounds after absorbed by plants (Jones, 2002).

Besides the higher percentages of P, K, Ca and Mg for CHE-treated plants, the comparisons between the organic fertilizers revealed that FOL treated plants were significantly higher in P percentage, whereas CKN was reported the lowest among all treatments (Figure 4.7B, C, D). On the other hand, all the organic fertilizer treated plants had significantly higher K percentage as compared to CTL plants (Figure 4.7C). It is found that both VER and FOL-treated plants had significantly higher percentage of Ca and Mg compared to CKN-treated plants (Figure 4.5D). A previous study done by Peavy and Greig (1972) supported the present result in terms of Ca, which was higher in spinach when grown using mineral fertilizer. Pfiffner *et al.* (1993) and Svec *et al.* (1976) also indicated that K was higher in beetroot and lettuce respectively, in mineral fertilizer treatments.

P contents in mature leaves ranged from 0.2 to 0.5%, toxicity occurs when P level in tissue exceeds 1.0% (Jones, 2002). Surprisingly, P contents of VER, FOL and CHE-treated plants were found to have more than 1.0% (Appendix B), suggesting occurrence of excess P contents in plants. K contents ranged from 1.5 to 4.0% for plant leaves while 6.0 to 8.0% for stem tissues of healthy plants. The results of this study indicate that all treatments caused deficiency in K contents of plants (Appendix B). This may be due to toxicity during N uptake for CKN treated plants as ammonium restricts K uptake by competing for root uptake binding sites, even though CKN is found to have highest K content among all fertilizers. CHE treated plants remained high in K contents due to the high K contents in chemical fertilizer. VER and FOL were already low in K contents (Appendix B), thus causing low K contents in plants.

Adequate levels of Ca in mature leaves ranged from 0.5 to 1.5% (Jones, 2002). Plant toxicity is observed for FOL and CHE-treated plants, whereas plants treated with other treatments had normal range of Ca (Appendix B). The symptoms of excess Ca in vegetables are uncommon, but appear mainly as a result of Mg or K deficiencies in plants (Jones, 2002). This is true for VER and FOL treatments as Ca uptake is raised to a different extent by K deficiency. The normal concentration of Mg in plants ranged from 0.15 to 0.40%. The trends of Mg contents in plants subjected to different fertilizer treatments were similar to that of Ca contents, but to a lesser extent (Figure 4.5D). Deficiencies occurred in all treatments as plants were affected by soil pH as low as 5.7 (Appendix B). Jones (2002) suggested that Mg uptake is strongly influenced by pH, its availability markedly decline when the soil pH is below 5.5. On the other hand, CKN treated plants had significantly lower K, Ca and Mg contents may be due to high N contents. This is supported by Jones (2002) that showed ammonium fertilization often can cause K, Ca and Mg deficiencies.

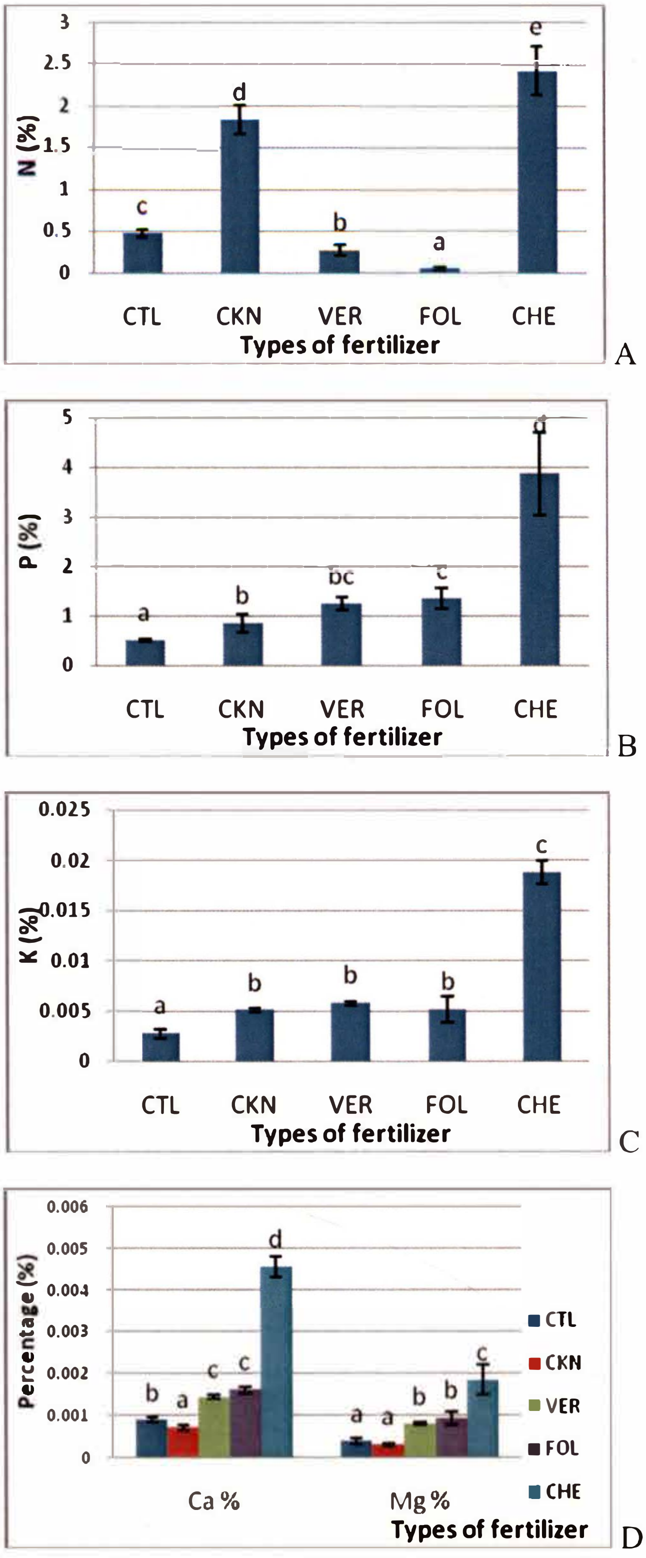

Figure 4.5: Effect of chicken manure (CKN), vermicompost (VER), foliar biofertilizer (FOL), chemical fertilizer (CHE) and control (CTL) on the macronutrients; percentage of Nitrogen (A), Phosphorous (B), Potassium (C), Calcium and Magnesium (D) for *Brassica rapa* (L.) after four weeks of fertilization. Vertical bar represent standard deviation (SD) of mean. Treatment with the same letter denotes no significant difference at $P<0.05$.

4.9 Micronutrients

The contents of micro-elements such as B, Cu, Fe, Mn and Zn for CHE-treated plants had similar pattern as observed in macronutrients. Besides, a comparison among the organic fertilizers showed that FOL treated plants was significantly higher in Cu, Fe and Mn contents. Both CKN and VER treated plants were higher in B contents. Mn contents had an ascending trend with CTL<CKN<VER<FOL<CHE in terms of concentration found in plant tissues. However, there was no significant difference in Zn contents among all the organic fertilizers treated plants (Figure 4.6). Several previous studies on micronutrient elements were found to be similar to the present results. Smith (1993) has shown that Fe content was higher in wheat treated with inorganic fertilizers. Kansal *et al.* (1981) reported that Zn was actually higher in inorganic fertilizer treatment. Similarly, conventionally grown celeriac was also higher in Zn as compared to organically grown celeriac (Leclerc *et al.*, 1991). Meanwhile, Warman and Havard (1997) have demonstrated that Mn and Cu were higher in NPK fertilizer treated carrots compared to organic fertilizer treatment.

The average B contents in most plants are 20 ppm on a dry weight basis (Jones, 2002). *Brassica* crops have high B requirements. Cu contents in most plants ranged from 2 to 20 ppm while sufficient range in leaves is from 3 to 7 ppm. The normal range of Fe contents found in plant tissues is from 50 to 75 ppm. Foliar levels of Mn ranged from 10 to 200 ppm while the sufficiency range in leave is from 10 to 50 ppm. The sufficiency range for Zn in leaves is from 15 to 50 ppm. The results of this study show that none of the treatments had positive effect on providing sufficient micronutrients to the plants (Appendix B), except that CHE treatment was much better

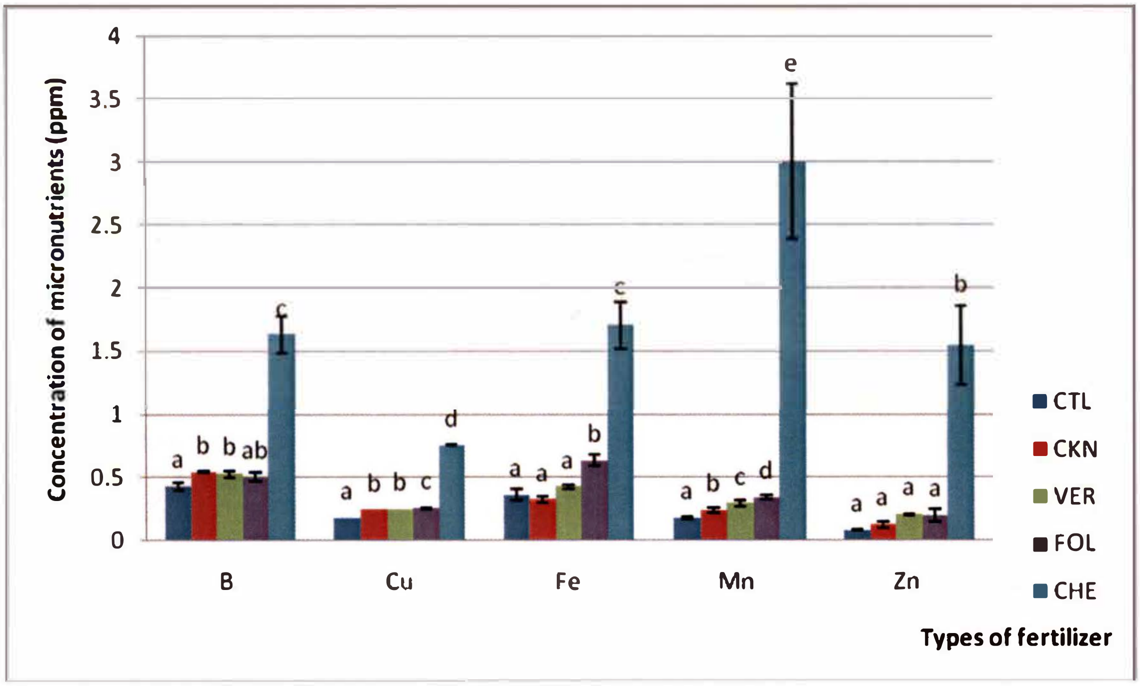

Figure 4.6: Effect of chicken manure (CKN), vermicompost (VER), foliar biofertilizer (FOL), chemical fertilizer (CHE) and control (CTL) on the micronutrients; percentage of Boron (B), Copper (Cu), Iron (Fe), Manganese (Mn) and Zink (Zn) for *Brassica rapa* (L.) after four weeks of fertilization. Vertical bar represent standard deviation (SD) of mean. Treatment with the same letter denotes no significant difference at $P<0.05$.

than other organic fertilizers in enhancing micronutrients uptake by plants. High levels of K decrease B uptakes in plants (Jones, 2002), however in the present study the high K contents in CHE treated plants did not affect B contents as B contents were still significantly higher than other treatments (Figure 4.6).

It is suggested that the high contents of P from CHE may increase the mobility and solubility of Fe in plants and indirectly increase the rate of Fe uptake (Figure 4.6). Cu significantly inhibited the uptake of Zn, and vice versa. This may be due to interference of Zn with Cu at the root absorption site. In addition, Cu may stimulate the uptake of Mn as both nutrients had the same trend among treatments (Figure 4.6). Jones (2002) reported that high P levels can cause depressed growth, primarily by decreasing the uptake and translocation of Zn, Fe and Cu. However, excess P contents in VER, FOL and CHE treated plants in present study did not cause negative effects on Zn, Fe and Cu contents of the plants as compared to CKN treatment. Lower micronutrients in CKN, VER and FOL treated plants were primarily due to low input of micronutrients from the fertilizers.

Interestingly, although CHE does not provide nutrients other than N, P, K and Mg (Appendix C), the high rate of application of the stated nutrients enhance the overall nutrient contents in plants. Apart from that, FOL was able to enhance Cu, Fe and Mn to a significant extent compared to other organic fertilizer treatments. FOL may have been formulated with higher micronutrient contents. Generally CKN did not enhance the micronutrient contents in plants although it had very high N contents (Appendix C). VER brought similar effect towards plant micronutrient contents as compared to CKN, except significantly higher in Mn contents.

CHAPTER 5

CONCLUSION AND SUGGESTION

5.1 Conclusion

It can be concluded that the cultivation of *Brassica rapa* at soil pH 5.7 and sandy loam soil treated with various fertilizer treatments have significant effects on its growth and post-harvest quality. Chemical fertilizer treated plants attain maximum growth, higher concentration of plant pigments and high levels of macro and micronutrients but have poor visual quality and low firmness of the leaves. Comparison among the organic fertilizers shows marginal effects on the nutrients contents of plants, except chicken manure treated plants have higher N contents while foliar biofertilizer has positive effects on the P, Ca, Mg, Cu, Fe and Mn contents of the plants. Overall, vermicompost and foliar biofertilizer are not able to enhance the growth and quality of *B. rapa*. On the other hand, the organic chicken manure has significantly enhanced the visual appearance, and firmness of leaves better than other treatments. In general, the results of this study may explain the trend on consumers' preference on organic vegetables due to better physical and texture attributes.

5.2 Suggestion for further study

The present study using pot experiments have shown a significant result on the quality of *Brassica rapa* affected by organic and inorganic fertilizers. Future study can be undertaken under field conditions to verify the trends demonstrated by this study. The field trials may resemble the actual scenario of vegetable quality as affected by fertilizers, especially the influence of nutrient leaching and weather condition on the vegetable cultivation.

The effect of organic fertilizers such as composted animal manure, vermicompost and biofertilizer on the post-harvest quality of vegetables should be further examined. Experiments could be conducted at different rates of organic fertilizers combined with chemical fertilizer on the quality of vegetables.

Different species and variety of vegetable crops should be further examined of their responses towards organic and inorganic fertilizers. Additional parameters could be added to assess the post-harvest quality of vegetables. These include vitamin C contents, dietary fiber, glucose level, organoleptic quality, and a series of proximate analysis test. Experiment could also be done to assess the vegetable quality during storage in order to examine the post-harvest quality and shelf lives of vegetables on few day intervals corresponding to different fertilizer treatments.

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APPENDIX A

Effect of different types of fertilizer on the growth parameters, visual quality, colour, plant colour pigments and firmness of *Brassica rapa*.

Treatments	CTL	CKN	VER	FOL	CHE
Edible leaves (no/plants)	6.25 ± 1.26 ^{a}	13.00 ± 1.63 ^{c}	10.50 ± 2.38 ^{bc}	7.50 ± 1.00 ^{ab}	22.75 ± 2.63 ^{d}
Fresh weight (g)	1.05 ± 0.17 ^{a}	14.28 ± 2.34 ^{d}	6.13 ± 1.55 ^{c}	1.90 ± 0.17 ^{b}	87.57 ± 13.27 ^{e}
Leaf area (cm²)	4.45 ± 0.31 ^{a}	24.70 ± 3.55 ^{b}	24.96 ± 6.23 ^{b}	13.71 ± 2.48 ^{a}	46.68 ± 5.37 ^{c}
Visual quality (scale)	2.75 ± 0.50 ^{a}	8.75 ± 0.50 ^{c}	5.00 ± 0.82 ^{b}	3.00 ± 0.82 ^{a}	5.75 ± 0.96 ^{b}
L*	57.35 ± 5.78 ^{b}	52.19 ± 5.59 ^{ab}	51.81 ± 1.04 ^{ab}	55.04 ± 8.73 ^{b}	42.96 ± 1.22 ^{a}
a*	-20.51 ± 1.36 ^{a}	-19.60 ± 1.77 ^{ab}	-20.62 ± 0.48 ^{a}	-20.44 ± 1.70 ^{a}	-17.50 ± 0.84 ^{b}
b*	36.31 ± 5.52 ^{a}	31.92 ± 6.49 ^{a}	33.23 ± 1.12 ^{a}	35.95 ± 6.87 ^{a}	25.53 ± 2.11 ^{a}
Chlorophyll a (μg/ml)	2.40 ± 0.52 ^{a}	3.21 ± 0.46 ^{a}	3.47 ± 0.48 ^{a}	2.73 ± 0.60 ^{a}	4.95 ± 0.75 ^{b}
Chlorophyll b (μg/ml)	1.73 ± 0.20 ^{a}	2.07 ± 0.25 ^{ab}	2.26 ± 0.32 ^{ab}	2.21 ± 0.48 ^{ab}	2.79 ± 0.35 ^{b}
Carotenoid (μg/ml)	0.62 ± 0.15 ^{a}	0.83 ± 0.09 ^{a}	0.82 ± 0.11 ^{a}	0.64 ± 0.12 ^{a}	1.13 ± 0.16 ^{b}
Leaf firmness (force, g)	83.92 ± 11.98 ^{b}	170.91 ± 17.63 ^{c}	33.56 ± 8.91 ^{a}	16.53 ± 1.07 ^{a}	18.23 ± 3.22 ^{a}
Stem firmness (force, g)	368.78 ± 49.44 ^{a}	618.68 ±105.95 ^{b}	619.01±143.89 ^{b}	262.87 ± 24.26 ^{a}	836.49 ± 57.92 ^{c}

Mean within the same row with different letter denotes significant different ($P<0.05$).

APPENDIX B

Effect of different types of fertilizer on the macronutrients and micronutrients contents of *Brassica rapa*.

Treatments	CTL	CKN	VER	FOL	CHE
N%	0.47 ± 0.05^{c}	1.84 ± 0.18^{d}	0.27 ± 0.06^{b}	0.05 ± 0.03^{a}	2.42 ± 0.29^{e}
P%	0.51 ± 0.03^{a}	0.86 ± 0.18^{b}	1.25 ± 0.13^{bc}	1.36 ± 0.21^{c}	3.87 ± 0.82^{d}
K%	$2.78\times10^{-3}\pm0.46\times10^{-3\,a}$	$5.07\times10^{-3}\pm0.13\times10^{-3\,b}$	$5.77\times10^{-3}\pm 0.19\times10^{-3\,b}$	$5.14\times10^{-3}\pm 1.32\times10^{-3\,b}$	$18.79\times10^{-3}\pm 1.13\times10^{-3\,c}$
Ca%	$0.88\times10^{-3}\pm 6.10\times10^{-5\,b}$	$0.70\times10^{-3}\pm 6.32\times10^{-5\,a}$	$1.43\times10^{-3}\pm 4.87\times10^{-5\,c}$	$1.60\times10^{-3}\pm 7.70\times10^{-5\,c}$	$4.55\times10^{-3}\pm 24.20\times10^{-5\,d}$
Mg%	$0.38\times10^{-3}\pm 8.30\times10^{-5\,a}$	$0.30\times10^{-3}\pm 2.50\times10^{-5\,a}$	$0.79\times10^{-3}\pm 3.00\times10^{-5\,b}$	$0.93\times10^{-3}\pm 16.00\times10^{-5\,b}$	$1.84\times10^{-3}\pm 35.00\times10^{-5\,c}$
B (ppm)	0.4322 ± 0.0307^{a}	0.5419 ± 0.0057^{b}	0.5283 ± 0.0262^{b}	0.5028 ± 0.0326^{ab}	1.6287 ± 0.1445^{c}
Cu (ppm)	0.1830 ± 0.0005^{a}	0.2456 ± 0.0014^{b}	0.2499 ± 0.0007^{b}	0.2570 ± 0.0042^{c}	0.7514 ± 0.0054^{d}
Fe (ppm)	0.3624 ± 0.0425^{a}	0.3247 ± 0.0213^{a}	0.4252 ± 0.0120^{a}	0.6336 ± 0.0460^{b}	1.6990 ± 0.1882^{c}
Mn (ppm)	0.1770 ± 0.0082^{e}	0.2393 ± 0.0167^{d}	0.2941 ± 0.0203^{c}	0.3428 ± 0.0184^{b}	3.0004 ± 0.6167^{a}
Zn (ppm)	0.0817 ± 0.0018^{a}	0.1255 ± 0.0245^{a}	0.2058 ± 0.0077^{a}	0.1981 ± 0.0501^{a}	1.5416 ± 0.3078^{b}

Mean within the same row with different letter denotes significant different ($P<0.05$).

APPENDIX C

Nutrient composition of organic and inorganic fertilizers

Fertilizers	Inorganic complete fertilizer	Chicken manure compost	Vermicompost	Biofertilizer
	Nitrophoska 15-15-15-2	Midori Pure Active Organic Fertilizer	Vermicompost Organic Fertilizer Grade A	Max Growth (Foliar fertilizer)
Nutrient composition	N – 15%	N – 6%	N – 1.3%	Not stated
	P – 15%	P – 2%	P – nil	
	K – 15%	K – 18%	K – 1.5%	
	Mg – 2%	Mg – 2%	Ca – 1.7%	
		S – 3.31ppm	Mg – 0.77%	
		Cu – 69ppm	S – 0.14%	
		Zn – 415ppm	B – 30.93ppm	
			Cu – 17.37ppm	
			Mn – 308.77ppm	
			Zn – 70.50ppm	

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