EFFECT OF ORGANIC AND INORGANIC FERTILISERS ON THE GROWTH, YIELD AND NUTRITIONAL QUALITY OF CHOY SUM (*Brassica rapa* var *parachinensis*)

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ABSTRACT

Soil fertility is essential for sustainable crop production. Inorganic fertilisers are expensive and do not bring excellent crop production in the long term. Combined application of different fertiliser sources can act as an alternative way to overcome this problem. A study was carried out at the Faculty of Sustainable Agriculture, Universiti Malaysia Sabah Sandakan Campus, in order to determine the effect of organic and inorganic fertiliser on the growth, yield and nutritional quality of choy sum (*Brassica rapa* var *parachinensis*). The treatments used were full recommended rate of compound NPK fertiliser (340 kg ha^{-1}), full recommended rate of poultry manure fertiliser (PM) (20 t ha^{-1}), combination of half recommended rate of NPK fertiliser and full recommended rate of poultry manure (170 kg NPK ha^{-1} + 20 t PM ha^{-1}), combination of full rate NPK and half rate poultry manure (340 kg NPK ha^{-1} + 10 t PM ha^{-1}), combination of half rate NPK and half rate poultry manure (170 kg NPK ha^{-1} + 10 t PM ha^{-1}) and control (without amendment). The experiment was laid out in a randomized complete block design (RCBD) with five replicates per treatment. Parameters studied were plant height (cm), stem girth (cm), number of leaves, leaf length (cm), leaf width (cm), fresh weight of shoot (g/plant), dry weight of shoot (g/plant) and vitamin C content (mg/100g). The treatment means were compared by Least Significant Differences (LSD) at 5% probability level. Results revealed that, at harvesting day, there were only significant differences on growth of choy sum in terms of stem girth and leaf length among the different treatments. Highest stem girth (7.5 cm), leaf length (9.0 cm), leaf width (6.1 cm), leaf number (25), fresh weight (39.0g/plant) and dry weight (4.2 g/plant) of shoot were obtained from choy sum subjected to T5, combination of full NPK and half PM (340 kg ha^{-1} + 10 t ha^{-1}). Further, T2, full NPK (340 kg ha^{-1}) produced the highest plant height (24.6 cm) of the choy sum whereas T3, full PM (20 t ha^{-1}) showed the highest vitamin C content (50.0 mg/100g) in the choy sum. Thus, it could be stated that combination of organic and inorganic fertiliser is beneficial for the growth and yield of choy sum while vitamin C content of choy sum is dependent only on the organic fertiliser dose. Treatments which consist of combination of full recommended rate of NPK and half recommended rate of PM (340 kg NPK ha^{-1} + 10 t PM ha^{-1}) can be recommended for farmers to increase choy sum production and also reduce the cost of cultivation.

KESAN BAJA ORGANIK DAN INORGANIK TERHADAP PERTUMBUHAN, HASIL DAN KUALITI PEMAKANAN SAWI HIJAU (*Brassica rapa* var *parachinensis*)

ABSTRAK

Kesuburan tanah adalah penting untuk pengeluaran tanaman lestari. Baja bukan organik adalah mahal dan tidak dapat memberi hasil tanaman yang baik dalam masa jangka panjang. Penggunaan gabungan sumber baja yang berbeza boleh bertindak sebagai cara alternatif untuk mengatasi masalah ini. Oleh itu, satu kajian telah dijalankan di Fakulti Pertanian Lestari, Universiti Malaysia Sabah Kampus Sandakan, untuk menentukan kesan baja organik dan bukan organik terhadap pertumbuhan, hasil dan kualiti pemakanan sawi (*Brassica rapa* var *parachinensis*). Rawatan yang digunakan adalah 340 kg ha^{-1} baja sebatian NPK, 20 t ha^{-1} baja tahi ayam (PM), 170 kg ha^{-1} baja NPK gabung dengan 20 t ha^{-1} baja tahi ayam, 340 kg ha^{-1} NPK gabung dengan 10 t ha^{-1} baja tahi ayam, 179 kg ha^{-1} baja NPK gabung dengan 10 t ha^{-1} baja tahi ayam dan kawalan (tanpa sebarang baja). Eksperimen disusun dalam Rekabentuk Rawak Blok Lengkap (RCBD) dengan lima replikasi setiap rawatan. Parameter yang dikaji ialah ketinggian tumbuhan, batang lilitan tumbuhan, jumlah daun, kepanjangan daun, kelebaran daun, berat basah pucuk, berat kering pucuk serta kandungan vitamin C. Perbezaan antara rawatan dibandingkan (LSD) pada 5% tahap kebarangkalian. Hasil kajian menunjukkan bahawa hanya terdapat perbezaan bererti antara rawatan yang berbeza dalam parameter pertumbuhan seperti lilitan batang tumbuhan dan kepanjangan daun. Seterusnya, sawi yang dirawat T5, iaitu gabungan NPK penuh (340 kg ha^{-1}) dan kadar separuh baja tahi ayam (10 t ha^{-1}) adalah paling baik bagi pertumbuhan seperti lilitan batang tumbuhan (7.5 cm), panjang daun (9.0 cm), lebar daun (6.1 cm), bilangan daun (25), berat basah (39.0g/plant) dan kering pucuk (4.2 g/plant). Selain itu, NPK penuh (T2) telah menghasilkan ketinggian tumbuhan sawi tertinggi (24.6 cm) manakala rawatan PM penuh (T3) telah menunjukkan kandungan vitamin C tertinggi (50.0 mg/100g) dalam sawi. Justeru itu, ia boleh dikatakan bahawa gabungan baja organik dan bukan organik memberi manfaat kepada pertumbuhan dan hasil sawi manakala kandungan vitamin C daripada sawi bergantung hanya pada dos baja organik. Rawatan yang terdiri daripada gabungan NPK penuh dan separuh tahi ayam (340 kg NPK ha^{-1} + 10 t PM ha^{-1}) boleh disyorkan kepada petani untuk meningkatkan hasil pengeluaran sawi di samping mengurangkan kos penanaman.

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LIST OF SYMBOLS, UNITS AND ABBREVIATIONS

µg	Microgram
^0C	Degree celsius
ANOVA	Analysis of variance
cm	Centimetre
DEPI	Department of Agriculture and Fisheries
DOA	Department of Agriculture Malaysia
FAO	Food and Agriculture Organization
FSA	Faculty of Sustainable Agriculture
FSANZ	Food Standard Australia New Zealand
g	Gram
ha	Hectare
kg	Kilogram
kJ	Kilojoules
LSD	Least significant difference
m	Meter
mg	Milligram
mL	Millitre
mm	Millimetre
MRML	Most recent mature leaves
ppm	Part per million
RCBD	Randomized complete block design
rpm	Revolution per minute
SAS	Statistical analysis system
WAT	Week after transplanting

LIST OF FORMULAE

CHAPTER 1

INTRODUCTION

1.1 Background

Choy sum or Chinese flowering cabbage is a leafy vegetable belonging to the Brassicaceae family. It varies in height by around 20 to 30cm and has a short life cycle enabling the plant to be harvested within one and a half months (Edward, 2009). Choy sum is considered as a promising vegetable developed by farmers for local consumption and food security. In Malaysia, the choy sum also contributes to the export market as well as generates income for the country (DOA, 2013). Choy sum is known for its rich nutritional value. For example, choy sum is planted for its leaves which are rich in glucosinolates that are claimed to have anti-aging, antioxidant, and anti-cancer effects (Halkier and Gershenzon, 2006). Next, content of vitamin C in choy sum is significantly higher than other species in the same family which is good for normal collagen formation. It is also a good source of folate which contributes to normal immune system functions and other nutritional values that are good for health if regularly consumed.

Malaysia, just like many others parts of the world, has shown obvious increase in agricultural productivity during the last 50 years but then the conventional farming system has brought new concerns which is the future sustainability matter. Indrani *et al.* (2001) pointed out that conventional farming often has new technology, high capital investments for management, mono-cropping on a large scale for long periods and also extensive use of chemical pesticides and fertilisers. Negative effects have arisen such as exhausted soil organic matter, nutrient imbalance in soil and decline in the productivity of crops.

Organic fertiliser such as poultry manure is a good source of organic matter and nutrients to soil (Hue, 1994). Nutrients contained in organic fertilisers are released slower and have a longer storage time in the soil ensuring a long residual effect (Sharma and Mittra, 1991). In the long term, costs of production input will be reduced as the amount of fertiliser applied decreases. Water pollution problems such as leaching of chemical fertiliser to ground water can also be controlled. Additionally, application of organic fertiliser help to recycle wastes of plant or animal origin and minimise the use of non-renewable resources.

According to Ghani (2014), the USDA Foreign Agricultural Service in Global Agricultural Information Network (GAIN) report stated that Malaysian broiler meat (poultry) has reached around 1500 metric tonnes of production in 2014 and this output is expanding slowly year after year. This means that the poultry industry is positively established in the country. Huge amount of poultry manure produced from this industry if have not been disposed properly, will lead to bad odour exposure to the air. Poultry excretes cannot be used as fuel as well. Thus, it will be very useful to be processed into organic fertiliser or other bio-fertilisers because it supplies small nutrients to plants and increases soil organic matter content.

Furthermore, combined application of both organic and inorganic fertilisers can maximize the benefits of both fertilisers, increase the yield of crops and keep the environment sound (Hsieh *et al.* 1996). Inorganic fertilisers supply plant nutrients whereas organic fertilisers supply organic matter to improve soil structure. Based on all the facts stated above, this study was carried out to find the best amount and combination of fertilisers for maximum growth, yield and nutritional quality of choy sum as well as to promote sustainable farming system.

1.2 Justification

The rising population in Malaysia is causing an increase in food production to meet the rising demand. The drawbacks are intensification use of existing agricultural land since new land areas are limited. Input of nutrients is increasing and additional application of chemical fertilisers is inevitable. As a consequence, adverse environmental pollution, soil degradation and health issues become more critical. High levels of certain chemicals will be accumulated in plants and become toxic to us if we consume them. For example, high nitrates accumulated in leafy vegetables are converted into nitrites, which are toxic within themselves, and then turn into nitrosamines in our body leading to stomach cancer. Processed organic poultry manure can help to overcome this problem as they slowly release nitrogen into the soil. However, organic manure has low nutrient content and usually large amount are needed to supply enough nutrients for crop growth.

Since both organic and inorganic fertilisers have their pros and cons, this research is conducted to determine the most cost-effective fertiliser or fertiliser combination for farmers to reach maximum growth and yield of crops and at the same time improve soil health. Choy sum is chosen as it is one of the top five vegetables consumed by Malaysians (Fatimah, 2007) and it contains high nutritive value for human health.

1.3 Research objectives

To determine the effect of organic and inorganic fertilisers on the growth, yield and nutritional quality of choy sum.

1.4 Hypothesis

H0: There was no significant effect of organic and inorganic fertilisers on the growth, yield and nutritional quality of choy sum.

HA: There was a significant effect of organic and inorganic fertilisers on the growth, yield and nutritional quality of choy sum.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview of choy sum (*Brassica rapa* var *parachinensis*)

2.1.1 Origin, taxonomy and distribution

Brassica is a highly diverse genus of plants belonging to the family Brassicaceae or the cabbage family. It contains species that are of great economic importance, such as, oilseed, forage, ornamental and vegetable crops which are the mainstay of global food supplies together with cereal crops. Almost all parts of this species have been developed to be edible including roots, stems, buds, leaves, flowers, and seeds (AVRDC, 2000).

Brassica rapa is the first domesticated species in the Mediterranean region which expanded to Scandinavia, Germany, Europe and eventually towards Asia. Along the biological journey, great local variation in cultivation developed. For instance, *B. rapa* is planted as an agricultural crop in China whereas in India it is planted as an oilseed crop. *B. rapa* var *parachinensis* or Choy sum is a derivative of *B. rapa* var *chinensis* (Pak Choi) and a subspecies among seven vegetable groups of *B. rapa*. Choy sum is considered as leaf neeps and distinguished from the oil-yielding turnip rapes. It is originated in middle China and is also popularized for its edible young flowering stalks together with its leaves. Nowadays, the area of cultivation includes southern and central China and, southeastern Asian countries such as Indonesia, Malaysia, Thailand and Vietnam (Dixon, 2006). The phylogeny of the choy sum is described below:

Kingdom	: Plantae
Division	: Tracheophyta
Class	: Angiospermae
Order	: Papaverales
Family	: Brassicaceae
Genus	: *Brassica*
Species	: *rapa*
Subspecies	: *parachinensis*

2.1.2 Morphological characteristics

Choy sum is an annual vegetable that consists of tap roots and its height varies from 20-30cm with erect or sometimes prostrate growth habit (Dixon, 2006). It is characterized by yellow flowers borne on slight fleshy stems 0.5 to 1cm in diameter and is small in comparison with other leafy cabbages. Flowering of choy sum occurs when there are about 7-8 leaves on the plant (DEPI, 2009). Next, there are few leaves in the rosette, usually with only 1-2 leaf layers. There are long or short petiolate, oblong, bright green, stem leaves. These may be glabrescent to glabrous, green to purple-red and finely toothed when young. Lower stem leaves are ovate to nearly orbicular while upper stem leaves pass into narrow bracts. Inflorescences form as a terminal raceme, elongating when in fruit.

2.1.3 Ecological requirement

According to the Perak State Department of Agriculture (DOA, 2013), choy sum is a cool season crop that prefers uniform conditions, moderate moisture levels and reasonable sunlight. Optimum temperature is within 23-35 ^{0}C. Higher temperatures may result in thinner, tougher and less sweet shoots, or bolting. Excessive moisture can damage choy sum's leaves and their quality. Choy sum will grow on a wide range of soil types if they are fertile and high in organic matter. Soil should be well drained and have an ideal pH of 6.0 to 7.0. When pH falls below 5.0, it is unfavourable for healthy choy sum growth.

Seeding rate for choy sum is 1.5kg per hectare and recommended spacing is 20 cm within rows and 10 cm between plants. For mineral soil, organic fertiliser can be added by basal dressing 4 ton per hectare into soil bed to ensure better growth of the plant. Side dressing with NPK fertiliser 15-15-15 can be carried out at the second and third weeks after sowing (DOA Perak, 2013).

2.1.4 Nutritional benefits

Choy sum is an excellent source of vitamin C, folate, iron and potassium (FSANZ, 2010). It is also a source of vitamin A, fiber and has a high water content which contributes to a healthy digestive system. Furthermore, choy sum contains antioxidant properties that give us protection against heart diseases and cancer. Its flower shoots and younger leaves are used in salads, or stir-fired, light boiled or added to meat.

Vitamin C or ascorbic acid is important to human as it cannot be synthesized by the body itself. Thus, choy sum acts as a cheaper source of vitamin C. Vitamin C contributes to normal collagen formation for the replacement of dead skin and bone cells. Davey *et al.* (2000) mentioned that vitamin C, which includes ascorbic acid and its oxidation product, dehydroascorbic acid, performs many biological functions inside the body such as enzyme cofactor, radical scavenger and as a donor or acceptor in electron transportation in plasma membrane. Ascorbic acid is able to scavenge the superoxide and hydroxyl radicals. Table 2.1 below shows the nutritional value of every 100g fresh yield of choy sum.

Table 2.1 The nutritional value of choy sum per 100g of fresh yield.

	Nutritional value per 100 g of fresh yield
Energy	71 kJ
Protein	1.3 g
Fat	0.3 g
Carbohydrates	0.9 g
Dietary fibre	2.8 g
Sodium	13 mg
Folate	425 µg
Vitamin C	46 mg
Vitamin A	230 µg
Iron	1.7 mg
Potassium	340 mg

Source: FSANZ, 2010.

2.1.5 Production and economic importance

Fatimah (2007) reported that choy sum is among the top five vegetables in terms of per capita consumption expressed on a fresh weight basis in Malaysia. Vegetable and Cash Crops Statistic Malaysia from the Department of Agriculture (DOA, 2013) showed that hectareage of *brassica* in Malaysia has increased rapidly from year 2009 (around 7,036) to year 2013 (around 14,579 hectare) while harvested areas cover 14,291 hectares.

The production is around 250,060 metric tons which contributes to a value of RM 745,178,000 income for the vegetable industry. According to DOA (2013), Johor has the largest harvested area for *brassica* which is around 4471 hectares and thus choy sum is exported to the primary export market of Malaysia's vegetable industry, Singapore. Additionally, most of the choy sum production is locally consumed and there is a concentration of production in home and market gardens around cities.

2.2 Organic poultry manure

According to Nwaiwu *et al.* (2010), organic manure is derived from decaying material of plant or animal origin for example poultry, cow, horse, sheep manure, animal urine, bat guano, bone meal, blood meal, fish meal or fish emulsion, seaweed, sludge and green manure such as leguminous cover crops. Quality and nutrient content of each organic manure therefore varies widely. For example, nitrogen content in poultry manure is more concentrated than that in cattle manure.

Poultry manure is commonly collected from chickens, ducks, geese, turkeys, pigeons and parrots. These manures are obtained from poultry industries. Robinson and Beauchamp (1982) mentioned that most of the feeds for poultry will turn into manure and not animal proteins. Therefore, poultry manure is a valuable source of fertiliser. Poultry manure is produced during the normal operation of hatcheries, broiler production and egg laying production (Agriculture and Agri-Food Canada, 1990). Majority of poultry manure is produced in broiler and layer operation industries. In general, commercially available poultry manure is handled in solid form through air drying, pulverizing, and packing in plastic bags of different sizes (McCall, 1980).

2.2.1 Composition of organic poultry manure fertiliser

The chemical composition of poultry manure will vary in several factors, for instance source of manure, feed of animals, age of animals, condition of animals, manner of storage and handling and litter used (Mariakulandai and Manickam, 1975). Table 2.2 below shows the composition of freshly voided poultry manure (Ohio State University Extension, 2012). Calcium content in egg laying chicken is higher than in growing broiler and turkey manures. This means that poultry manure used as fertiliser can have liming effects to the soil. Furthermore, nitrogen in poultry manure comes in different forms such as uric acid, ammonia salts, and organic (fecal) matter. This affects the nitrogen availability for plants. For fresh manure, nitrogen is in the quick-release inorganic or mineral form. For uric acid, which is the predominant form of nitrogen, will transform rapidly into ammonia gas and evaporate if it is not mixed into the soil.

Table 2.2 Composition of freshly voided poultry manure

Component	Laying Chicken	Growing Broiler	Growing Turkey
Total Nitrogen	1.0-1.8 %	1.4-2.2 %	1.2-2.5 %
Phosphorus (P)	0.8-1.2 %	0.9-1.2 %	1.0-1.4 %
Potassium (K)	0.5-0.7 %	0.5-0.8 %	0.5-0.8 %
Calcium	3.3-4.8 %	1.2-2.5 %	1.0-2.3 %

Source: Ohio State University Extension, 2012.

2.3 Effect of organic and inorganic fertilisers on leafy vegetables

2.3.1 Physiological growth response

Organic and inorganic fertilisers are the main suppliers of primary macronutrients such as nitrogen (N), phosphorus (P) and potassium (K) which are required in maximum quantities by plants. Miller and Donahue (1990) stated that among all the essential nutrients, nitrogen is the most often limiting nutrient in plants and is needed in highest quantities for normal plant growth. Ammonium NH_4 and nitrate NO_3 are the forms of nitrogen available for plant uptake. Nitrogen acts as a constituent of chlorophyll for photosynthesis to be carried out smoothly. High photosynthetic activity when there is sufficient supply of nitrogen can lead to vigorous vegetative growth of plants with a dark green colour appearance.

Phosphorus is the second most limiting nutrient in plant growth. Normally, total concentration in surface soils varies from 0.02 % to 0.10 % because mineral phosphate forms are not readily soluble for plants to absorb. Plants take up P in the form of HPO_4 and H_2PO. Phosphorus plays a vital role in photosynthesis and protein makers. Inadequate supply of P will result in low photosynthetic activity, low RNA synthesis, low protein maker and finally depressed growth. Next, for potassium, it is important in plant growth and reproduction. It also plays a role in photosynthesis, carbohydrates transport, protein formation, control of ionic balance, regulation of plant stomata and so on (Munson *et al.*, 1985).

Besides providing macronutrients, organic materials from organic fertiliser supply carbon into the soil and provide substrate for microbial growth. Decomposition activities in soil increases when soil microbial diversity rises. In turn, substantial quantities of N, P and S and even smaller amount of micronutrients or trace elements are released into the soil nutrient bank. Various nutrients are then converted to available forms by microbes for plant usage. For instance, some of the organic substances released during mineralization may act as chelates that help in the absorption of iron and other micronutrients to overcome micronutrient deficiency in soil (Schlecht *et al.*, 2006). Iyamuremye and Dick (1996) also pointed out that organic materials could increase P availability by forming complex (or chelate) with ions of iron (Fe) and aluminium (Al) in soil solution, preventing the precipitation of phosphate.

Organic fertilisers increase soil organic matter content and slowly improve soil physical properties such as soil structure, soil bulk density and aeration (Agbede *et al.*, 2008). According to Mbatha (2008), good soil aeration is more favorable for the roots to grow deeper, ensuring strong stems and taller plants especially in sandy soil or high nutrient depleted areas and soil with high percentage of clay. For instance, addition of poultry manure can stimulate root growth of carrots to a depth of 10cm. Mbatha (2008) also stated that roots that grow to deeper soil layers despite providing strong plants, allow plants to extract more nutrients and water. Growth rate of plants such as height, stem diameter, number of leaves and leaf area are enhanced. Furthermore, humus that comes from organic fertilisers or poultry manure is also an excellent substrate for plant growth (Suge *et al.*, 2001).

On the other hand, research has shown that the early stage of vegetables growth under organic fertiliser when compared with those receiving inorganic fertiliser is much slower (Mbatha, 2008). This could be attributed to the much lower levels of nitrogen and phosphorus available to plants at the early stages in organic fertilisers. Conversion of organic forms to an available forms of N is relatively slow during the first 4 weeks after addition of organic fertilisers. About 60 % of N only become available during the first 6 weeks in the soil and the remaining 40 % of N is available at the next crop or season (McCall, 1980). Similarly, phosphorus and other plant nutrients may not all be available until the next season. Only potassium is readily available in the first season. Therefore, timing for organic fertiliser application is vital. With the aid of soil microorganisms in producing plant growth regulators which are important for plant vegetative growth and photosynthetic activities, healthier vegetable growth in the later stages could be recompensed by the organic manures (Arisha *et al.*, 2003).

2.3.2 Yield

Takebe *et al.* (1995) reported that increments in leaf dry weight is due to a combination of nitrogen with plant matter produced during photosynthesis such as glucose, ascorbic acid, amino acids and protein. Since leaves are the main organ of photosynthesis, any increments in number of leaves and leaf area by organic and inorganic fertilisers will boost the rate of plant photosynthesis due to more light being intercepted. Hence, high leaf dry weight will be obtained. Next, improved plant growth by fertilisers always leads to better carbohydrate build up which increases the crops' yield and their quality components (Mbatha, 2008).

Various studies have compared the yields of organically fertilised plants with that of inorganic fertilised plants. First, the positive effect of the application of inorganic fertilisers on crop yields and yield improvements have been shown through studies by Gontcharenko (1994) and Haraldsen *et al.* (2000), where vegetables such as cucumber, tomatoes and cabbage treated with inorganic fertiliser obtained higher yields than that with organic fertilisers. Different results shown by another study at which organic fertilised leafy vegetables such as lettuce and amaranthus having more dry mass than the inorganically fertilised (Mbatha, 2008). Slower release of nutrients from organic fertilisers into the soil turn up to plant greater nutrients use efficiency. Amount of nutrients lost through leaching, run off and volatilization are smaller (Rauton, 2007).

Organic fertiliser if utilised regularly can fulfil crop's nutrient requirements (FAO, 2008). In drier areas which contain some heavy soils, the land structure and fertility will be improved if continually nourished with poultry manure. Consequently, higher yield of crops will be produced. Additionally, fertilisers application time must be taken into consideration in order for the organic fertilised plants to produce higher yield. Otherwise, yields of organically treated plants can decline due to slower nutrient release as well as nutrient uptake (Warman, 2000).

2.3.3 Nutritional quality

According to Tey *et al.* (2009), Malaysia has to cope with the challenge of trade regulations and requirements from the World Trade Organization (WTO), whereby only high quality of vegetables and fruits can penetrate the foreign markets such as Europe and developed countries. In the domestic agriculture food market, demand on higher quality vegetables has risen as more citizens are able to afford high quality food. Therefore, producing vegetables and fruits with good nutritional quality is concerned by agriculturist.

Although the plant's genetic makeup, stage of maturity and climatic conditions play more important roles in the nutrient composition of crops, sources of fertiliser can still affect the quality of vegetables and fruits (Hassan *et al.*, 2012). Organically produced vegetables have shown higher concentration of desirable internal quality compounds such as vitamin A, B1 (thiamin), B2, B12 (cynocobalamin), C, E, β-carotene, soluble protein, carbohydrates, total sugars (sucrose, glucose and fructose) and mineral compounds (Ca, K, Mg, S and Na) if compared to inorganically fertilised vegetables (Liu and Li, 2003). Vitamin C or ascorbic acid is significantly varied with the rates and sources of nutrients (Hassan *et al.*, 2012).

Shree *et al.* (2014) stated that organically managed crops usually have higher vitamin C than conventionally fertilised crops. It is because when a plant is exposed to more nitrogen, protein production will increase and carbohydrate synthesis will reduce. Vitamin C levels are also minimised because it is synthesised from carbohydrates. In organically managed soil, plants are exposed to lower amount of nitrogen and organic crop would be expected to maintain higher Vitamin C as well. Furthermore, organic fertilisers promote growth of soil microorganisms which affect the soil ecology and plant

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