EFFECTS OF INORGANIC FERTILIZERS LEVELS ON GROWTH AND YIELD OF CHILLI (*Capsicum annuum* L.)

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ABSTRACT

The experiment was carried out to study the effects of inorganic fertilizers on growth and yield of chilli in polybags under the rain shelter structure at Faculty of Sustainable Agriculture, University of Malaysia Sabah, Sandakan campus. NPK Green 15: 15: 15 were applied as basal application for the vegetative growth of the chilli plant. Four levels (5, 10, 15, 20 gram per plant) of inorganic fertilizer NPK Blue Special (N: P_2O_5: K_2O: Te = 12:12:17:2) were evaluated on chilli (*Capsicum annuum* L.) with five replications for each treatment. The application of NPK Green were stopped until the chilli plant starts to fruit. Five gram per plant of NPK Blue fertilizer recommended by the Department of Agriculture (DOA) was act as the control. This experiment was arranged in Completely Randomized Design (CRD). Chilli plant were planted in 20 topsoil filled polybags sized 16x16 cm. Parameters such as plant height (cm), stem girth (cm), fresh fruit weight (g), fruit length (cm), fruit diameter (cm), number of fruits per plant, and the total fruit yield (g) was assessed in the experiment. The result of the experiment shows highly significant difference ($p<0.01$) in the plant height, stem girth, fresh fruit weight, total fruit number per plant and total fruit yield of chilli while the fruit length and fruit diameter shows a significant difference at $p<0.05$. The best treatment was shown by the 15 gram per plant of NPK level whereas the least was shown by the control treatment (5 gram per plant). This indicates that the application of inorganic fertilizer NPK significantly enhanced and promotes the growth and yield of chili (*C. annuum* L.)

KESAN PENGGUNAAN BAJA TIDAK ORGANIK TERHAPAD KADAR PERTUMBUHAN DAN HASIL CILI *(Capsicum annuum.* L*)*

ABSTRAK

Kajian ini telah dijalankan untuk menilai kesan baja tidak organik terhadap kadar pertumbuhan dan hasil cili yang ditanam didalam polibeg di bawah struktur lindungan hujan Fakulti Pertanian Lestari, Universiti Malaysia Sabah, Kampus Sandakan. Empat kadar (5, 10, 15 dan 20 g pokok^{-1}) baja tidak organik (N: P_2O_5: K_2O: Mi = 12:12:17:2) telah dinilai keatas pokok cili (*Capsicum annuum* L.). Lima gram per pokok untuk kadar baja yang disarankan oleh Jabatan Pertanian bertindak sebagai rawatan kawalan. Setiap rawatan mempunyai 5 replikasi dan telah disusun dalam Rekabentuk Rawak Lengkap. Pokok cili telah ditanam dalam 20 polibeg berukuran 16x16 sentimeter yang diisi dengan tanah atas. Hasil kajian iaitu ketinggian pokok (sm), ukur lilit batang (sm), berat basah buah (g), panjang buah (sm), diameter buah (sm), jumlah buah per pokok, dan jumlah hasil kutipan (g) telah dinilai sepanjang kajian dijalankan. Hasil kajian menunjukkan perbezaan sangat bererti ($p<0.01$) terhadap ketinggian pokok, ukur lilit batang, berat basah buah, jumlah bilangan buah per pokok dan jumlah hasil buah. Manakala panjang buah dan diameter buah menunjukkan perbezaan bererti pada $p<0.05$. Rawatan yang terbaik telah ditunjukkan dalam penggunaan kadar baja tidakviorganik (NPK) 15 gram per pokok manakala rawatan yang terendah ditunjukkan dalam rawatan kawalan (5 gram per pokok). Kajian ini menunjukkan bahawa penggunaan baja tidak organik NPK telah memberi kesan positif terhadap kadar pertumbuhan dan pengeluaran hasil pokok cili (*C. annuum* L.).

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LIST OF SYMBOLS, UNITS AND ABBREVIATIONS

%	Percentage
ANOVA	Analysis of Variance
cm	Centimeter
CV	Coefficient of Variation
DAT	Days After Transplant
g	Gram
g $plant^{-1}$	Gram per Plant
GR	Guard Row
K	Potassium
K_2O	Potassium oxide
LSD	Least Significant Difference
Mg	Magnesium
mm	Millimeter
N	Nitrogen
P	Phosphorus
P_2O_5	Phosphate
SAS	Statistical Analysis of Software
Te	Trace Element

CHAPTER 1

INTRODUCTION

1.1 Background

Chilli (*Capsicum annuum* L.) belongs to the family Solanaceae. Chilli originated from South America is now a major vegetable in Southeast Asian countries. Among the domesticated species, *C. annuum* is the most economically important and includes both mild and pungent fruit types. *C. annuum* is the most commonly cultivated species and all green chilies in the market and most of the dry chilies belong to this species (AVRDC, 1989). The hot chilli is one of the most important commercially grown vegetables in the tropics, mostly for own consumption and some for export to the other countries.

C. annuum chilli peppers, members of the genus *Capsicum,* are common throughout the cuisines of the world, and have become such a key element in, for example, Southeast Asian cuisines, that are commonly believed by locals that chilies are indigenous to these regions (Bletter *et al.*, 2010).

In Malaysia, chilli is an important vegetable on the basis of commercial value. *C. annuum* L. and *C. frutescence* are commonly grown in Malaysia. Chilli has a rapidly growing period of 90 to 150 days. Chilli pepper is a crop plant grown extensively under rain-fed conditions with very high yields when the rainfall is about 600 to 1250 mm (Channabasavann and Setty, 2000). The soil's pH ranged between 5.5 and 5.9 though acidic, it is the preferred soil range for good growth and optimum yield of pepper. It was reported by Salako *et al.*, 2007 that the best pH range for chilli pepper production was 5.0 to 6.0.

The Food and Agriculture Organization reported that Asia produced 18,055,581 metric tons of chilies from 1,154,310 hectare of land in 2010 (FAO 2010). In 1996 the total area planted with chilli was 3,553 ha out of a total of 18,212 ha of fruit vegetables (Anon, 1996a). Malaysia exported 7,995 tonnes of fresh chilli worth RM4.921 million and imported 13,318 tonnes worth RM8.916 million in 1996 (Anon. 1996a). According to FAOSTAT (2011), the total harvested area of chilli in the world was 1,897,946 ha and in Malaysia the area was about 2,986 ha.

Table 1.1: Nutritional content of chilli

Content (g)	Amount/100g
Protein	2.8
Carbohydrate	9.5
Fat	0.7
Fibre	0
Calcium	0.015
Iron	0.0018
Phosphorus	0.08
Calium	0
Natrium	0
Beta Carotene	0.00273
Vitamin B1	0.0002
Vitamin B2	0.0001
Vitamin C	0.1755
Niacin	0.0007
Water	93.5

Source: Anon, 1990

Chilies contain numerous chemicals including steam-volatile oil, fatty oils, capsaicinoids, carotenoids, vitamins, protein, fiber and mineral elements (Bosland and Votava, 2000) and are variously used for different purposes because of their nutritional value, flavour, aroma, texture, pungency and colour in a wide assortment of foods, drugs, and cosmetics, while some are cultivated ornamentally, especially for their brightly glossy fruits with a wide range of colours, shape and sizes. The pungency nature of chilli is due to the presence of the alkaloid capsaicin that provides flavouring and therapeutic effects. The fruit is rich in vitamins such as vitamins A and C and minerals such as K and P.

The chilli plant is a perennial, but often grown as an annual. The production period ranges from 2-12 months, depending on the variety, management and occurrence of diseases. Chilli fruits can be marketed fresh or in dried form. Most of chilli processing industries preferred dried chilli because it is more economical to process in this form. The high demand has encouraged more farmers to grow this crop.

Fertilizers are classified into two categories – inorganic and organic. Inorganic fertilizers include urea (source of N), TSP (source of P), muriate of potash (source of K) and compound fertilizers such as NPK Green 15:15:15 and NPK Blue Special 12:12:17:2. Inorganic fertilizers could be granular, coated, slow-release, etc. Organic fertilizers (manures) are derived from the wastes of plants and animals. Decomposed organic materials (composts) are the most common organic fertilizer.

Compound fertilizers are frequently used because it is more convenient to purchase, transport, store and apply one product than several as is the case if one chooses to use individual nutrient sources such as urea, muriate of potash or TSP. Compound fertilizers are often a good choice for providing a basal application of nutrients, including secondary and micro-nutrients, prior to or at planting. Many commercial fertilizers are mixtures of compounds (compound fertilizers) which provide substantial amounts of N, P and K. Another commonly recommended fertilizer for sandy soils is 12:12:17:2. This latter mixed fertilizer contains 2 kg of micronutrients in addition of 12 kg of N, 12 kg of P_2O_5 and 17 kg of K_2O per 100 kg of fertilizer.

Meticulous fertilizer management techniques are required for producing high yield and good quality of chilli. This is true for N and K which directly influence growth, maturity, and yield and fruit quality. Chilli has also been shown to respond very well to the application of fertilizer (O'Sullivan, 1979; Akande *et al.*, 2008) and produced well when it is adequately supplied with the essential nutrients (Peck and MacDonald, 1975). Aliyu *et al.* (1991) reported that day to 50% flowering, maturity days, number of fruits per plant, fruit diameter and length of chilli pepper was significantly affected by nitrogen application.

The successful production of crops requires a farmer to make maximum use of all available resources. One of the most important and necessary resources is fertilizer, which provides the nutrients needed by plants to grow properly and yield a quality product. Fertilizers account for one-third or more of crop yields. Inadequate fertility starves plants. Excess fertility is wasted and can cause physical injury and death to plants as well as pollution to the environment.

Ewulo *et al.*, (2007) reported that NPK fertilizer increased growth parameters of pepper such as number of leaves, plant height, stem diameter and number of branches. It is necessary therefore to supply plants with precise and balanced amounts of nutrients needed for their optimal growth and development but avoiding excessive amounts that can be eventually lost to the environment.

1.2 Justification

Chilli (*Capsicum annuum* L.) are fruit-vegetable that commonly found in multiethnic of Malaysian's daily food menu. They are extremely popular for the huge content of vitamin C and total soluble phenolics higher than other vegetables commonly recognized as a source of this substance (Marinova *et al.*, 2005; Anil Kumar *et al.*, 2009). Nowadays chilli is an important vegetables crops and used world-widely as for flavour, aroma and add colour to foods (Zhuang *et al.*, 2012). The fruits are an important vegetable crop for the fresh market and processed products.

Malaysia is a net importer for fresh chilli. To overcome the constraints of chilli production, it is desirable to select the high yielding of chilies. In retrospect, research efforts for chilli improvement in Malaysia are mainly for fresh chilli consumption.

Efforts made so far are to convince producers to realize that they can get higher prices for better quality when graded. Maximize production of chilli for higher profit. Grading at producer's level need to be encourage, in particular, at the regulated markets and co-operative marketing societies, so that good quality chilies are offered for sale, and benefit are accrued to buyers by getting desired good quality and sellers by getting premium price.

The major constraints in chilli cultivation are lack of suitable varieties and problems of pests and diseases. The local chilli varieties are very variable in agronomic characteristics resulting in inconsistent and generally low yield. High yields of Capsicum have been obtained in the tropics mainly through the use of improved genotypes, fertilizers and good cultural practices (Saha *et al.*, 1994). Inorganic fertilizers are relied upon to improve crop yields and maintain soil fertility.

The total requirements of chilli in Malaysia reached up to 50 thousand tons per year and due to insufficient national production, then country need to expend a considerable amount of currency to import chilli from neighboring countries. However, the average chilli productivity in Malaysia is still very low and it is necessary to increase both cultivation techniques as well as crop productivity to achieve desirable production.

Different rates of NPK fertilizer application have been studied at various locations to ascertain the appropriate quantity required for optimum yield in pepper (Dwivedi, 1993). Five grams of NPK Blue Special (12:12:17:2) fertilizer per plant every week were suggested by the Department of Agriculture (DOA, 1993). This study therefore aimed to study and determine the effects and the optimum levels of compound NPK fertilizer (NPK Blue 12:12:17:2) on the growth and yield of chilli.

1.3 Objectives

1. To determine the optimum level of inorganic fertilizer (NPK) application for chilli.

2. To study the effect of inorganic fertilizer (NPK) levels on the growth and yield of chilli.

1.4 Hypothesis

H_o: There is no significant difference between the levels of inorganic fertilizer (NPK) on the growth and yield of chilli.

H_a: There is significant difference between the levels of inorganic fertilizer (NPK) on the growth and yield of chilli.

CHAPTER 2

LITERATURE REVIEW

2.1 Chilli Production

2.1.1 Global Production of Chilli

Capsicum annuum L. is the most commonly cultivated species and all green chilies in the market and most of the dry chilies belong to this species. *C. annuum* L. locally called 'tatase' is a very important fruit vegetable in the tropics and the world second most important vegetable after tomatoes (Olaniyi and Ojetayo, 2010). Chilli originated from the America with their cultivars is now grown around the world because they are widely used as food and medicine (Mazourek *et al.*, 2009).

Pepper or *Capsicum* species, is an important vegetable crop in many countries of the Tropical and Subtropical ecology where it is an important component of the diets (Adetula and Olakojo, 2006). This crop is very important for agricultural economy and is used in processing industries. The most familiar peppers names are chilli, bell, red, green or just called as pepper (Faustino *et al.*, 2007).

The commercial importance of paprika both as a spice and a vegetable with large scale cultivation in both tropical and sub tropical regions are increasing (Kannan *et al.*, 2009). Owing to its high cash value and consumption rate the annual trade of chili is approximately 17% of total spice trade in the world (Ahmed *et al.*, 2000). Total world production of peppers was estimated to be 14-15 million metric tonnes a year (Wiess, 2002).

2.1.2 Chilli Production in Malaysia

Table 2.1(a): Hectareage and Production of Vegetables by Types in Malaysia 2011-2013

Type of Commodity/ Years	2011		2012		2013	
	Planting area (ha)	Production (mt)	Planting area (ha)	Production (mt)	Planting area (ha)	Production (mt)
Chilli	2597	28,766	3001	29,834	3016	29,983

Source: Department of Agriculture (DOA), 2013

Table 2.1(b): Hectareage and Production of Vegetables by Types in Sabah 2012

Type of Vegetable	Hectareage	Producing Area	Production (Tonne)
Chilli	69.6	68.9	632.4

Source: Department of Agriculture (DOA), 2013

Table 2.1(a) shows the planting areas of chilli plant in Malaysia from the year of 2011 until 2013. From the table, it shows that the planting area in hectareage and the production of chilli in metric tonnes increase by year. This makes chilli the highest, second to long bean, in hectare among the fruit vegetables cultivated in Malaysia. Most of the locally produced chilli is consumed and processed in fresh form. Table 2.1(b) shows the hectareage and production of chilli in Sabah was 632.4 tonnes in the year of 2012.

2.2 Botanical of Chilli

Table 2.2 (a): Plant Morphology of Chilli

Parts	Description
Roots	Consist of tap and fibrous root.
Stems	Branch and green in colour depends on type of cultivar.
Leaves	Broad-ovate shape. Leaf size from small to medium depends cultivar.
Flowers	White in colour, pendant-shaped.
Fruits	Elongated
Seeds	Yellow in colour and weight ranged from 3.5-5.0 gram/1000 seeds.
Type of Pollination	Self-pollinated.

Source: Jabatan Pertanian, 1992

Table 2.2 (b): Types of Chilli Cultivar

Cultivar	Descriptions
MC 4	Height: 60-70cm Fruit length: 7-10cm Fruit weight: 10-15 g/fruit, less spicy. Resistant to anthracnose and virus. Yields: 12-20 tons/ha.
MC 5	Height: 100-200cm Fruit length: 10-15cm Fruit weight: 10-15 g/fruit, spicy. Resistant to anthracnose and virus. Yields: 15-25 tons/ha.
MC 11	Height: 80-110cm Fruit length: 8-10cm Fruit weight: 7-10 g/fruit, spicy. Resistant to anthracnose, virus and also to *Choanephora.* Yields: 17-24 tons/ha.
MC 12	Height: 60-80cm Fruit length: 10-13cm Fruit weight: 12-14 g/fruit, spicy. Resistant to anthracnose and *Choanephora.* 'Escape' to virus. Yields: 15-29 tons/ha.
Kulai	Height: 70-80cm Fruit length: 10-15cm Fruit weight: 7-10 g/fruit, very spicy. Less resistant to anthracnose and virus, resistant to wilt bacteria. Yields: 15-20 tons/ha.

Source: Jabatan Pertanian (1992)

2.3 Uses and Nutritional Value of Chilli

Chili peppers, members of the genus capsicum, are common throughout the cuisines of the world, and have become such key element in, for example, Southeast Asian cuisines, that are commonly believed by locals that the chilies are indigenous to these regions (Bletter *et al.*, 2010). Pepper is good source of vitamins A, C, E, B1 and B2, Potassium, Phosphorus and Calcium. Moreover, it is one of the valuable medicinal plants in pharmaceutical industries because of high amount of antioxidant, capsaicin and capsicum as main active substances.

Capsaicinoids are alkaloids that are important in the pharmaceutical industry for their neurological effectiveness (Hayman and Kam, 2008). Pepper that are fresh is known as the very good source of vitamin C and E and as well as provitamin A and carotenoids, they also known for its antioxidants properties (Krinsky, 2001; Perucka and Masterska, 2007; Navarro, *et al.*, 2006; Chatterjee, *et al.*, 2007; Conforti, *et al.*, 2007; Deepa, *et al.*, 2007; Serrano-Martinez *et al.*, 2008).

Vitamin C, including ascorbic acid and its oxidation product (dehydroascorbic acid), has many biological activities in the human body due to its antioxidant properties (Davy *et al.*, 2000; Yahia *et al.*, 2001). Pepper is normally used as a spice in the preparation of soup and stew when cooked with tomatoes and onions. It can also be used as a condiment and extensively in flavouring of processed meat, colouring certain food preparation and also used for medicinal purposes (Alabi, 2006). In human consumption, peppers and bell peppers are an important source of nutrient such as in providing carotenoids, phenols, vitamin C, foliates (Philips *et al.*, 2006).

The nutrient components of peppers are mainly relying on the variety and their stages of maturity (Ozgur *et al.*, 2011). In peppers, there are phytochemical property that have many biochemical and pharmacological properties which includes antioxidants, anti-inflammatory, antiallergenic and anti-carcinogenic activities (Lee *et al.*, 2005). It also has been proven that, ripe red peppers can reduce the risk of cancer (Nishino *et al.*, 2009). In addition, peppers also contributed antimicrobial property (Wahba *et al.*, 2010). There are also very few research have been carried out in identifying and compare the vitamin C content, total phenol compound, capsaicinoids content and antioxidant characteristic among different varieties of green chilli with different maturity stages.

There are many properties that differ in chilli from other fruit-vegetables, such as in their shape, size, colour, flavour and heat either they can be hot, sweet, fruity, earthy, smoky and floral. Varieties and stages of maturity also have great influence on chilies quantity (Kanner *et al.*, 2006; Sanatombi and Sharma, 2008). Scientific research has proven that, *C. annuum* L. is the only crop that produce alkaloid compound called capsaicinoids, which is responsible for the hot test.

2.4 Fertilization

Fertilizer is one of the major factors of crop production. Among the factors, nitrogen is very much essential for good plant establishment and expected growth (Uddin, 2003). Use of fertilizers has amused a great significance in recent years in vegetables production. The need for continued increase production and yield per hectare of vegetables requires the increase amount of nutrients.

Fertilization rates refer to the amount of fertilizer needed at a given time in the crop cycle. Rates are usually expressed as a weight per surface area to be applied or a weight per plant for example in kilogram per hectare or gram per plant. Efficient use of fertilizer is necessary to balance and maintain the optimum levels at which fertilizer could be used without being detrimental to the soil.

Optimum dose of fertilizer increase the pepper growth, development and maximize the yield of pepper. A large amount of herbicides, pesticides, and fertilizers is applied every year to achieve maximum productivity of chili and to meet the growing demand, the use of chemical fertilizer in India has increased 170 times in last 50 years (FAO, 2010).

Under field conditions, the application of a given nutrient should be the summation of the crop requirement plus the potential losses due to leaching and volatilization minus the soil nutritional contribution. High yields of Capsicum have been obtained in the tropics mainly through the use of improved genotypes, fertilizers and good cultural practices (Saha *et al.*, 1994). Inorganic fertilizers are relied upon to improve crop yields and maintain soil fertility.

The quantity of nutrients which the farmer needs to apply depends on the yield potential of the cultivar, the level of available plant nutrients already in the soil, and growth conditions. Since vegetative and reproductive stages overlap in this group of crops, they need a continuous and steady supply of nutrients throughout their life span. It is necessary to adopt appropriate nutrient management practices which help to supply nutrients in quantities adequate to just meet crop demand and minimize losses, thereby increasing the nutrient use efficiency. Such practices will be environmentally friendly, and lead to sustainability in vegetable production.

Based on their absorbed volumes and accumulation in plants, these essential elements are divided into two groups; macronutrients and micronutrients. The macronutrients are Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg) and Sulphur (S) while Iron (Fe), Manganese (Mn), Zinc (Zn), Boron (B), Copper (Cu), Molybdenum (Mo), Chlorine (Cl) and Nickel (Ni) are considered as micronutrients (Barker and Pilbeam, 2007).

Pepper plants are relatively efficient in being able to absorb nutrients from the soil in comparison with other shallow-rooted vegetable crops, such as lettuce and leafy greens. The nutritional requirements of different pepper types are understandably highly variable in the literature, mainly due to cultivar, soil type, and cultural practice variations. However, some manuals establish ranges of pepper absorption of the macronutrients N, P and K at 156-160 kg per hectare, 14-24 kg per hectare, and 160-205 kg per hectare respectively (IMCC, 1984; Maynard and Hochmuth, 2007).

Pepper has also been shown to respond very well to the application of fertilizer (O'Sullivan, 1979; Akande *et al.*, 2008) and produced well when it is adequately supplied with the essential nutrients (Peck and MacDonald, 1975). Optimum dose of fertilizers increase the proper growth, development and maximize the yield of sweet pepper.

The other management practices are fertilizer application, especially nitrogen in terms of kind and rate. It had been observed that Nitrogen fertilizer is an essential component of any system in which the aim is to maintain good yield (Law-Ogbomo and Egharevba, 2009).

Application of N in four splits at 30-day intervals has been recommended by Singh *et al.* (1988) to achieve maximum yields and profits in chili production. Subhani *et al.* (1990) obtained the highest yield of chili when both N and K were applied in four splits at planting, 30, 60 and 90 days after transplant (DAT).

In respect to this, nitrogen, phosphorus and potash is of paramount importance, nitrogen stimulates vegetative growth and phosphorus helps in early establishment of crop, formation of fibrous and strong root system and thereby helping absorption of nutrients from the soil and finally contributing towards rapid growth in seedling. Potash helps in the biosynthesis of carbohydrates. It also helps in moisture regulation within plant system there by reducing the ill effects of moisture stress at the time of water deficiency (Challiah, 2003).

Nitrogen is involved in the synthesis of protein, nucleic acids and hormones; a deficiency of nitrogen in plants is marked by reduced growth and yellowing of leaves (Lynn and Alexander, 2005).

Ewulo *et al.* (2007) reported that NPK fertilizer increased growth parameters of pepper such as number of leaves, plant height, stem girth and number of branches. The increase in vegetative growth had been attributed to increase synthesis of carbohydrates as a result of fertilizer application (Malik *et al.*, 2011).

2.4.1 Effect on Compound Inorganic Fertilizer (NPK) on Growth of Chilli

Height and leaf number increase have been reported with the application of nitrogen fertilizer (Akanbi and Adeniran, 2010).

The increase in plant height was mainly due to the low organic matter and N, P and K content of the experimental site which has been made available to the growing pepper seedlings, thus influence the growth of the plant. These results are in accordance with the findings of Alabi (2006), Adewale *et al.* (2011) Ewulo *et al.* (2008) which stated that the plant height of pepper, garlic and tomato increased significantly as the fertilizer rate increased.

The first two weeks after transplanting might therefore be the critical age at which pepper will respond very well to efficient NPK fertilizer utilization. It had been reported that a deficiency of nitrogen in plants is marked by reduced growth and yellowing of

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