KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY
KUMASI- GHANA

COLLEGE OF AGRICULTURE AND NATURAL RESOURCES
FACULTY OF AGRICULTURE
DEPARTMENT OF HORTICULTURE

INFLUENCE OF DIFFERENT SOIL AMENDMENTS AND CULTIVAR TYPES ON POSTHARVEST PERFORMANCE OF THREE (3) COMMERCIAL TOMATOES (*Lycopersicon esculentum*, Mill)

NYAMAH, EDMOND YEBOAH

September, 2011.

CERTIFICATION

I, Nyamah, Edmond Yeboah hereby declare that this work herein now submitted, as dissertation is the results of my own investigation. Reference made therein, are however respectively acknowledged.

NYAMAH EDMOND YEBOAH	……………………	…………….
STUDENT	SIGNATURE	DATE

Dr. B.K. MAALEKUU	………………….	……………
SUPERVISOR	SIGNATURE	DATE

Dr. B.K. MAALEKUU	……………………….	……………
HEAD OF DEPT.	SIGNATURE	DATE

DEDICATION

This work is dedicated to Almighty God for giving me precious life up till now. It is also dedicated to my parents Mr and Mrs Nyamah and my entire siblings for their Prayers and support given me.

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to Dr. B. K Maalekuu, who worked tirelessly in supervising this work and the entire lecturers of the Department of Horticulture, College of Agriculture, Kwame Nkrumah University of Science and Technology especially Dr. Banful, Mr. F. Appiah, Mr. P. Kumah and Dr. Joe A. Manu of CSIR-CRI, for their diverse contributions toward the realization of this work. I am especially grateful for their constructive criticisms, guidance and support at every phase of this project.

I am highly grateful to Miss Rita Mahama, Mr. Daniel Oppong-Sekyere, Mr. Clement Abugri, Mr. Emmanuel Odame and Miss Dede Soga for their unflinching support. Special acknowledgment goes to Mr. and Mrs. Nyamah and my siblings Frank Nyamah, Salina Nyamah, Francisca Nyamah and Joseph Nyamah for their moral and financial support. God bless you all. Amen.

ABSTRACT

Three (3) tomato (*Lycopersicun esculentum*, Mill) cultivars (Power (local), Royal (exotic) and Cal. J (exotic) were harvested from fields amended with 'Asasewura' cocoa fertilizer (NPK 0-22-18 +9CaO+6s+5MgO(s) at (250kg/ha), Sulphate of ammonia (125kg/ha), poultry manure (1.1kg/ m^2) and Control (no amendment) after basal NPK 15-15-15 at 250kg/ha on 'Asasewura cocoa' fertilizer and Sulphate of ammonia amended fields. The main study was carried out in the major season (May – August, 2009) after preliminary studies from October to January 2008 at the Department of Horticulture, Kwame Nkrumah University of Science and Technology in Kumasi, Ghana. The experiment was conducted to test the influence of different soil amendments and cultivar types on postharvest performance of tomato fruits. Selected quality traits of tomato fruits harvested at the pink colour stage were evaluated after seven (7) days storage under average temperatures of 26.85°C and average relative humidity 85.75%. Significant differences among the cultivar types ($P < 0.001$) and soil amendments ($P < 0.002$) were observed in the quality traits selected. Fruits of Royal and Power on average ranked best and least respectively among the cultivar types in postharvest performance among the quality traits evaluated. Fruits harvested from soil amended with NPK plus 'Asasewura' cocoa fertilizer on average performed better in postharvest quality than fruits harvested from fields amended with NPK plus Sulphate of ammonia, Poultry manure and Control respectively. Significant interactions were indicated among cultivar types and soil amendment types in fruit total soluble solid ($P < 0.016$) and pericarp thickness (0.019) but none in other fruit quality traits evaluated. Significant correlations ($P < 0.01$ and $P < 0.05$) were observed among the quality traits evaluated. Fruit weight loss showed significantly but negative correlation between fruit firmness (-0.71) and shelf life (-0.71)

but indicated significant but positive correlation between membrane ion leakage (0.63) and fruit decay (0.57) respectively. Fruit pericarp thickness showed significant but positive correlation between general appearance (0.69), pericarp weight (0.68) and total soluble solids (0.73).

TABLE OF CONTENTS

LIST OF TABLES

TABLE **PAGE**

LIST OF APPENDICES

APPENDIX **PAGE**

LIST OF ABBREVIATIONS

ABBREVIATIONS

CONT – Control (no amendment) field

CSIR - Centre for Scientific and Industrial Research

EC – Electrolyte Concentrate

FAO – Food and Agricultural Organisation

GIPC – Ghana Investment Promotion Council

MM –millimetres

N - Newton

NPK + SA – NPK plus Sulphate of ammonia amended fields

NPK+ CA – NPK pus ‘Asasewura’ cocoa fertilizer amended fields

ºC- Degree Celsius

PM – Poultry manure amended fields

RH –Relative Humidity

SRI-Soil Research Institute

CHAPTER ONE

1.0 INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is a major horticultural crop with an estimated global production of over 120 million metric tons (F.A.O. 2007). It is one of the most widely used food crops in world vegetable economy (Chapagain and Wiesman, 2004). In Ghana, it is almost an obligatory ingredient in the daily diets of people across all regions. Compared to other vegetables used in Ghana, tomatoes are normally used in large quantities (Ellis *et al*., 1998). Tomatoes are low in fat and calories, cholesterol-free and a good source of fibre, vitamins A and C, β-carotene, lycopene (provide protection against a broad range of epithelial cancers) and potassium (Kabelka *et al*., 2004).

The total land area utilized for tomato production in Ghana increased from 28,400 hectares in 1996 to 37,000 hectares in 2000 (GIPC, 2001). Despite the large area put under cultivation and a range of inorganic fertilizers comprising NPK 15:15:15, NPK 20:20:0, Sulphate of Ammonia and Urea (Ellis *et al*., 1998) and organic fertilizer such a Poultry manure (FAO, 2005) as part of soil amendment fertilizers used in some major tomato growing areas in Ghana, fresh tomato fruits do not meet the demand of the consumers since lots of losses are counted.

In countries like Ghana, a postharvest loss of fresh fruit is estimated to be about 20 to 50 percent (Kader, 1992). These losses may likely emerge from inability of the fruits to maintain certain postharvest qualities such as lower weight loss (water loss), fewer fruit cracks, decay incidence, longer shelf life among others. The high postharvest losses have resulted in a relative increase in the importation of tomato paste with a reported increment from 3,300 tons in 1998 to 24,740 tons in 2003, an increase of 650 percent (FAO, 2006). Cultural practices such as nutrient application, water supply and harvesting methods are claimed to be factors influencing quality of tomato before and after harvest (Watkins and Pritts, 2001).

Kader, (2005) reported that, the reduction of postharvest losses of perishables is of major importance when striving for improved food security in developing countries like Ghana. Different fruit production and quality responses are obtained among genotypes and crop environments (Ho, 1999). Cultivar types have been reported to influence fruit decay and weight loss in sweet pepper (Bosland, 1993; Maalekuu *et al.*, 2004).

It is against this background that the present study was aimed at investigating the effects of different soil amendments on postharvest performance of three (3) commercial tomato cultivars in Ghana.

The objectives of this study were to evaluate the effect of two conventional and one organic fertilizer on postharvest quality of three (3) commercial tomato cultivars. The research also sought to assess the postharvest quality of one local and two foreign tomato cultivars.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1. BOTANY

The tomato (*Lycopersicon esculentum* Mill), belonging to the Solanaceae family, is one of the most important and popular vegetables in the world (Peralta and Spooner, 2007). It is believed to have originated from Peru to Ecuador in Central to South America. The crop was introduced in West Africa in the 16^{th} and 17^{th} century by the Portuguese and has since become a very important crop used in many recipes and for different products (Norman, 1992). They are herbaceous, warm season crops which are annuals in temperate regions but can produce continued growth in tropical areas (Morgan and Lennard, 2000).

2.2 POSTHARVEST QUALITY ATTRIBUTES OF FRUIT

2.2.1 Weight Loss

Transpiration is a major cause of deterioration because it results in direct quantitative loss (loss of weight). Weight (water) loss is the principal cause of fruit softening and shriveling (Wilson *et al*., 1999). Maalekuu *et al*. (2004) reported that the effect of weight loss in commercial sweet pepper cultivars cause damage to fruit appearance and subsequent loss of market value. Respiration is a central process in living cells that mediates the release of energy through the breakdown of carbon compounds and this gives an indication of the overall metabolism of the plant part which utilizes the plant product as its substrate thereby leading to weight loss and shriveling (Kays, 1991). The respiration rate can, in fact, be used to predict the loss of weight from a produce. In marketing systems based on weight, respiration losses of carbon represents weight loss in the product hence a decrease in value (Kays, 1991). Weight (water) loss may differ in horticultural crops depending on their variety, size, texture, storage method and length of storage. Quality of most fruits and vegetables is affected by weight (water) loss during storage, which depends on the temperature and relative humidity conditions (Perez *et al*., 2003). The degree of water loss as studied in pepper fruits by Smith *et al*. (2007) is subject to effect of genotype and pre and postharvest environments as evidenced by year variation in fruit storage attributes. The dermal system (outer protective coverings) of commodity which includes the cuticle, epidermal cells, stomata, lenticles, and trichomes governs the regulation of weight (water) loss. Maalekuu *et al*. (2003) associated increase in weight (water) loss in pepper fruits to thin pericarp thickness and low epicuticular wax content. Bosland (1993) in his discoveries stated that, pepper varieties differ in water-loss rate during storage.

2.2.2 Fruit Firmness

The firmness is a criterion often used to evaluate fruit quality as it is directly related to fruit development, maturity, ripening and storage potential. It is also related to the likelihood of bruising when fruits are subjected to impact during handling (Lesage and Destain, 1996). Dobrzanski and Rybezyski (1998) considered firmness to be the principal characteristics of fruit, important for quality, harvest, maturity, and storage and shelf-life. High quality fruits have a firm appearance, uniform and shiny colour, without signs of injury, shrivelling or decay (Sargent and Moretti, 2002). Cultivar differences in weight loss are based on their morphological characteristics implying that firmness of fruits depends both on cultivar type and its morphological characteristics (Banaras *et al*., 1988).

Bosland, (1993) stated that, genetic background, growing conditions and fruit constitution at the time of testing (degree of ripeness, size, post-harvest handling and internal temperature) affect fruit firmness. Changes in firmness are highly correlated with surface appearance characteristics of tomatoes which related to colour, shape and sense of feel to firmness. Loss of pulp firmness during ripening varies with cultivar or hybrid. It is often inversely related to ripening, implying that, as ripening progressed, pulp firmness declined (Hibler and Hardy, 1994). Lownds *et al*. (1993) found a very pronounced decrease in fruit firmness to be associated with increase in weight loss during prolonged storage of pepper. Maalekuu *et al.* (2004) also showed strong correlations between weight (water) loss rates and both general fruits appearance (-0.69) and fruit firmness (0.93).

2.2.3 General Appearance

The appearance of tomato is greatly influenced by the presence and magnitude of defects. Kays, (1999) indicated that, general appearance of fruits plays an important role in making purchasing decisions and is affected mainly by fruits firmness, weight loss and decay incidence. Tomato colour, a factor for general appearance is another important factor in the consumer preference of tomatoes (Batu, 2003). Colour in tomato is the most important external characteristic to assess ripeness and postharvest life, and is a major factor in the consumer's purchase decision. Red colour is the result of chlorophyll degradation as well as synthesis of lycopene and other carotenoids, as chloroplasts are converted into chromoplasts (Fraser *et al*., 1994). Cultivar type influences fruit general appearance of pepper (Maalekuu *et al*., 2004).

2.2.4 Membrane Ion Leakage

Besides the wilting and dehydration of horticultural products during storage, deterioration of plant tissues is also of great concern to food and horticultural scientists. Evidence gathered to date supports membrane damage as the key event leading to a surge of biochemical reactions culminating in tissues deterioration (Maalekuu *et al*., 2005). Borsos-Matovina and Blakes (2001), defined membrane ion leakage as a measure of loss of membrane integrity resulting from membrane damage which leads to water loss and loss of other membrane-bound solutes. A strong relationship between rate of water loss and membrane ion leakage in ripe red pepper fruit during storage at 20ºC and 80-85 RH has been reported by Maalekuu *et al*. (2005) in which it was also stated that water loss rate, membrane ion leakage and lipids content appeared to have strong influence on membrane integrity in pepper fruit during storage. According to Maalekuu *et al*. (2005), membrane ion leakage which is an indicator of loss of membrane integrity was found to increase in pepper genotypes susceptible to high rates of water loss but low in genotypes less susceptible to water loss during storage. Their study indicated that membrane ion leakage and lipoxygenase were actively higher after storage than immediately after harvest. Kays (1991) associated the cause of leakage of membranes to dead cells which probably affects the enzyme-substrate interaction thus leading to reduced starch hydrolytic activity. A common feature accompanying senescence is increased membrane permeability, expressed as increasing leakage of ions which is associated with chilling of sensitive tissue and or senescence (Saltveit, 2002).

2.2.5 Pericarp Thickness

The pericarp of tomato fruits arise from the ovary wall, consisting of an exocarp or skin, a perenchymatous mesocarp with vascular bundles and a single-celled layer edocarp lining the loculus (Artherton and Rudich, 1986). The control of growth rate and the mechanical integrity of the tomato (*Lycopersicon esculentum*) fruit have, therefore, been attributed to the exocarp (Emmons and Scott, 1997). The mechanical performance of the exocarp or fruit skin, including the cuticle, the epidermis and a variable number of hypodermal cell layers, is however, of considerable economic significance for the integrity of the whole fruit. This affects not only fruit appearance, handling and storage, but also plays a prominent role in fruit cracking (Sekse, 1995). According to Lownds *et al*. (1993), pericarp thickness and epicuticular wax inhibits water loss. Maalekuu *et al*. (2003) reported that, it is possible that thin pericarp tissue and low epicutilar wax content increased weight loss in sweet pepper fruits. However, thicker pericarp tissues and high skin wax could probably contribute to fruit firmness. Firmness of pericarp tissues is a key component of both processing and fresh market cultivars (Artherton and Rudich, 1986). Wiedemann and Neihuis, (1998) stated that, the softening of fleshy fruits, such as tomato, during ripening is generally reported to result principally from disassembly of the primary cell wall and middle lamella. Softening in fleshy fruits is primarily due to cell wall modification (Mitcham, 1994), about 60% of the total cell calcium is found in the cell where it exerts a stabilizing function, influencing the texture, and firmness of fruits. Maalekuu *et al*. (2005) added that, fruit pericarp thickness, pericarp weight, pericarp surface area , initial water content and dry matter were highly associated with each other, but less so with water loss rate.

2.2.6 Fruit Decay

Principal causes of postharvest losses are decay, external damages incurred during harvesting and handling (Steven and Celso, 2005). Fruits rots are generally caused by opportunistic pathogens, those that cannot directly infect fruits tissues unless the tissues are stressed and these pathogens are ubiquitous in the natural environment. Mechanical injuries (such as bruises, cuts, punctures) that occur during harvest and handling are predominant causes for decay because they provide infection courts for decay pathogens. Once it initiates, a decay pathogen often can engulf the rest of the fruits (Sergeant *et al*., 1998). Fruits vary in their innate resistance to decay; those crops that have active wound-healing processes are more resistant (Niklis *et al*., 2002). Cultivar types can influence fruit (pepper) decay (Maalekuu *et al.*, 2004). Decay resulting from the growth of pathogenic microorganisms is the third important major factor in the deterioration of harvested fruits. Fruits have the ability to resist the attack of most microorganisms and such resistance is probably due to two factors: first, the barrier effect of the skin and second, a physiological characteristic of the commodity (O'brien *et al*., 1983). The skin made of cuticle and thick-walled epidermal and sub-epidermal cells can serve as a near impervious barrier to invasion by microorganisms. If the skin barrier is damaged, as often occurs during harvest, the fruit loses a part of its physical protection (O'brien *et al.*, 1983). Most pathological disorders found during post harvest handling of tomatoes originate in the field before harvest incidence and severity of these disorders are increased by physical injuries and chilling injury which make the fruits much more susceptible to decay (Atherton *et al.,* 1986).

2.2.7 Pericarp Weight

Fruit weight and composition depend on the balance between inward and outward fluxes to and from fruit (mostly water and carbon), which involve many different processes. Transpiration leads to water loss (Wu *et al*., 2003) and may decrease the fruit fresh weight and concentrate the soluble compounds. Cell division and cell expansion determine final fruit size and carbohydrate dilution within cells (Bohner and Bangerth, 1988; Ho, 1999). Characteristics of leaves (carbon source) could affect sugar production via photosynthesis. Carbon supply can be modified by environmental stresses or cultural practices. Studies on fruit thinning reduces the competition for carbon and promotes fruits size (weight) and sugar for instance, fruit thinning increased in similar proportions fresh and dry weights (Heuvelink,1997).

2.2.8 Dry Matter

Assessment of dry matter content is important because the high rate of respiration is accompanied by water loss during ripening (Dadzie and Orchard, 1997). High dry matter or low water content of the tomato has also been reported to affect fruit taste positively because the major components of tomato taste, sugars and acids, are more concentrated (Auerswald *et al*., 1999). Dry matter content reduces with time as the continuation of living processes within the produce uses up the food reserves (FAO, 1986). Dry matter and Total soluble solids are known to increase fruit quality (Loboda and Chuprikova, 1999), which fits well with consumers' demand for high quality produce (El-Saeid *et al*., 1996). Walsh *et al*. (2004) agree to the later that, fruit eating quality can be correlated to a number of variables, including sugar content, acid content, dry matter content, juiciness, texture, firmness and volatiles content. Opara and Tadesse, (2000) revealed that respiration also results in loss of fruit dry matter and weight.

2.2.9 Moisture Content

Fruits and vegetables contain large quantities of water in proportion to their weight. Norman, (1992) indicated that, tomato fruits contain about 93 percent moisture. In most fleshy or succulent postharvest products moisture content is often closely tied to product quality and a decrease in moisture content are counterproductive. The moisture content of post harvest products can have a pronounce effect on the rate of respiration. In general, respiration and metabolic processes decrease moisture content of the fruits leading to reduction in shelf life and quality (Kays, 1991). The rate of absorption of moisture (water) is nearly directly proportional to that of transpiration, a phenomenon of water loss (Pandey and Sinha, 2006).

2.2.10 Total Soluble Solids

Soluble solids content vary between cultivars and between stages of ripeness. For example, in some hybrids of banana soluble solids contents increase to a peak and then decline (the drop in total soluble solids may be due to the conversion of sugar in pulp alcohol), while in others, total soluble solids continue to increase with ripening (Hibler and Hardy, 1994). Studies have associated high consumer acceptance with high soluble solids concentration (SSC) in many commodities (Kader, 1994). According to Artes *et al*. (1999), the increment of soluble solids is caused by the biosynthesis processes or degradation of polysaccharides during maturity. Total soluble solid content increases with ripening, but may increase or decrease during storage as carbohydrates are utilized during fruit respiration and may increase due to the action of sucrose - phosphate syntheses which is activated by the ripening process itself, by ethylene, and by cool storage, (Mitchell *et al.,* 1991). Total soluble solids generally decreased significantly in tomato fruits with increasing impact bruising (Kirk and Sawyer, 1991), and increased mainly as result of hydrolysis of starch into soluble sugars (Wills *et al.*, 1989). Tomato fruits contain about 93 percent moisture and the rest being solids (Norman, 1992). Sugars, acids and their interactive are important for sweetness, sourness and overall flavour intensity in tomatoes. Fruit with high dry matter content usually also have higher soluble solids, and thus have better taste and flavour (Hao et *al*., 2000b).

2.2.11 Shelf-Life

Shelf life is defined as the period in which a product should maintain a predetermined level of quality under specified storage condition. Fruits shelf life during storage is an important feature from a producer's and a distributor's point of view, allowing the determination of risks arising from the loss of commercial value of fresh fruit in trade turnover (Radajewska and Borowiak, 2002). Tomato can be stored at ambient temperature for a period of up to 7 days. The shelf life is a period of time which starts from harvesting and extends up to the start of rotting of fruits (Mondal, 2000).

2.3. FERTILIZERS USED FOR TOMATO CULTIVATION IN GHANA

According to FAO, (2005) importation of compound fertilizers far exceeds the imports of the other fertilizers in Ghana. The second most important imported products are Ammonium Sulphate (AS) and Muriate of Potash (MOP). The imports of urea, single super phosphate and triple super phosphate are marginal. Ellis *et al.*, (1998) reported on range of conventional fertilizers comprising NPK 15:15:15, NPK 20:20:0, Sulphate of Ammonia and Urea as part of fertilizers used for soil amendment in some major tomato growing areas in Ghana. Among the conventional compound fertilizers found in Ghana is 'Asasewura', cocoa fertilizer, its formulation comprises: 0-18-22 NPK plus calcium, sulphur and magnesium which is used to amend cocoa growing fields. The important types of manure being used by farmers are cattle manure, sheep and poultry manure (FAO, 2005); of the three sources of manure, poultry manure contains the highest content of N, P_2O_5, K_2O, CaO, MgO nutrients which are important to plant growth. Ewulo, (2005) reported that, poultry manure contains high percentage of nitrogen and phosphorous for healthy plant growth. It has been reported that 30% of nitrogen from poultry litter is in urea or ammonium form and hence readily available (Sunassee, 2001).

2.4 EFFECT OF ORGANIC AND INORGANIC FERTILIZER ON FRUIT QUALITY

Raupp, (1996) indicated the positive effect of manure on the content of dry matter. Work conducted in Brazil showed that cattle manure significantly increased yield and mean fruit weight of melon (Faria *et al*., 2003). Unfortunately organic cultivation has a markedly negative effect on the yield (Hamouz *et al*. 2005); Moreover, organic fruits show more visible defects in comparison to conventional ones. This can make them less attractive to the consumers (Conclin and Tomson 1993). Recently, organic tomatoes in particular have been found to be of higher quality than conventional based on soluble solids (% Brix) and Bostwick consistency. Raupp (1996) reported on the positive effect of manure on total soluble solid content of vegetables. McCollum *et al*. (2004) found slight difference in soluble solids or acidity between conventional and organically grown fruit. Akande and Adediran (2004) found that poultry manure at 5 t ha^{-1} significantly increased tomato and dry matter yield. Barrett *et al.* (2007) in their results indicated significant differences in moisture content between tomatoes produced under conventional or organic production systems at almost all experimental fields; however, in two cases the moisture content of conventional tomatoes was higher and in a case the organic tomato moisture content was higher.

2.5 EFFECT OF NUTRITION ON FRUIT QUALITY

2.5.1 Nitrogen

Crisosto *et al*., (1995) reported that, excess nitrogen during the pre-harvest stage can also reduce fruit firmness. Produce that have been stressed by high rate of nitrogen or mechanical injuries is particularly susceptible to post harvest diseases (Bachmann and Earles, 2000). Negative effects of NH_4^+ nutrition in tomato production have often been connected with blossom-end rot damage of fruits (Siddiqi *et al*., 2002). With respect to fruit quality, a NH4 +-N-dominated nitrogen supply may markedly increase the incidence of fruits with blossom-end rot an effect which is ascribed to a depression of Calcium uptake by the enhanced external NH4 + levels (Akl *et al.* 2003; Heeb *et al.* 2005). Claussen (2002) observed an increase in both total and fruit dry weight when the ammonium fraction was 0.25. Parisi *et al*. (2006), reported that, high nitrogen supply (250 kg ha^{-1}) impaired some important quality characteristics of the tomato fruit, such as pH, soluble solids, glucose and fructose content, as well as the ratio of reducing sugars to total solids The inclusion of part of nitrogen in the form of NH4-N may improve fruit quality by increasing the content of sugars and organic acids when compared with solely nitrate nutrition (Flores *et al*., 2003). As reported by Heeb *et al*. (2005b), the supply of reduced nitrogen forms, such as ammonium or organic nitrogen, to tomato results in improved fruit flavours.

2.5.2 Potassium

Potassium plays a key role in charge balance and certain metabolic and transport processes, as well as turgor regulation (Dorais *et al.*, 2001); it influences fruit shape, reduces ripening disorders, and enhances acid concentration (Adams *et al*., 1978). Potassium provides resistance against pest and diseases and drought as well as frost stresses (Marschner, 1995). Williumsen *et al*. (1996) reported that high levels of potassium in tomato fruit stimulated the formation of organic acids that reduce fruit calcium availability and permeability of cell membranes. Hartz *et al.* (2005) indicated that, enhanced fertilization with potassium improves fruit colour. It also increases the concentrations of citric and malic acids, total solids, sugars, and carotene in tomato fruits, thereby improving its storage quality (von Uexkull, 1979). Potassium accumulates to a greater extent than nutrient elements, which leads to considerable demands for this mineral (Williams and Kafkaffi, 1998; Voogt and Sonneveld, 1997). A main cause for concern in elevating Potassium in the nutrients solution is its antagonistic effect on the uptake of other nutrients, such as Ca, N, or Mg. A high K: Ca ratio has been reported to increase blossom end rot (Bar Tal and Pressman, 1996). Potassium is also associated with carbohydrate chemistry, maintaining ionic balances in the plant and affects fruit quality (Jones, 1999). Potassium provides resistance against pest and diseases and drought as well as frost stresses (Marschner, 1995)

2.5.3 Calcium

An enhanced supply of calcium may reduce the incidence of shoulder check crack, another physiological disorder that leads to deterioration in fruit quality (Lichter *et al.* 2002). Calcium has received considerable attention in recent years due to its desirable effects; particularly it can delay ripening and senescence, reduce respiration, extend shelf life, increase firmness and reduce physiological disorders (Sharma *et al.*, 1996). Calcium affects fruit softening since it is essential in the structure of the cell wall and also influences cell membrane integrity (Fallahi *et al.*, 1997). Cheour *et al*. (1991), found that calcium based nutrition (calcium chloride) delayed the ripening of fruits (strawberry) and also increased firmness of fruit at harvest and during storage. Insufficient Calcium supply will increase the biosynthesis of carotenoids (Key, 1991) which are responsible for tomato fruit colour (Dorais *et al.*, 2001). Calcium treatments have been commercially applied in apple to increase the shelf life and reduce the post- harvest disorders (Sharma *et al.* 1996). Calcium plays a crucial role in maintaining the structural and functional integrity of plant membranes and has significant roles in cell wall stabilization, regulation of ion transport and selectivity and activation of cell wall enzymes (Asharf *et al*., 2004).

2.5.4 Phosphorus

It appears that the variation of Phosphorus supply in soil grown tomato crops does not significantly influence the total soluble solids of the tomato juice, (Oke *et al*. 2005). According to Adb-Alla *et al*. (1996), phosphorus increased total soluble solids and acidity contents. It also improves the colour of skin and pulp, taste, hardiness and vitamin C content.

2.5.5 Magnesium

Magnesium, a major constituent of cell walls (Jones, 1999), is vital for the process of photosynthesis and, therefore, for the life of the plant in general (Jones, 1999). Magnesium is not directly involved in the fruit quality of tomato, although under conditions of severe Magnesium deficiency the size and overall appearance of the fruit may be reduced. However, an increase of the Magnesium supply above the standard recommended levels, though not toxic for the plants, may considerably increase the incidence of blossom end rot, unless accompanied by a commensurate increase in calcium supply (Hao and Papadopoulos, 2004). Magnesium also appears to stabilize the ribosomal particles in the configuration necessary for protein synthesis and is believed to have a similar stabilizing effect in the matrix of the nucleus (Mengel and Kirkby, 2001).

2.5.6 Sulphur

Zelená *et al*, (2009) in their studies on the effect of sulphur fertilization on Lycopene content and colour of tomato fruits and concluded that, sulphur applied in the form of different fertilizers (ammonium, sodium, potassium and calcium sulphates) in all cases significantly increased content of lycopene in fruits and red colour of tomato homogenate in both cultivars. Although it had very similar effect on content of lycopene in tomato fruits in both cultivars, growth of plants and yield of fruits were influenced differently in dependency on cultivars. Higher dose of sulphur positively influenced yield of fruit in cultivar Šejk, but decreased yield of fruits in cultivar Proton (Zelená *et al.,* 2009)

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 EXPERIMENTAL SITE

The field experiment was conducted at the Experiment fields of the Department of Horticulture at the Kwame Nkrumah University of Science and Technology (KNUST) in Kumasi during the period between May and August, 2009 after a preliminary experiment was conducted from October to January 2008 at the same location. The field is sandy loam soil and is located at latitude 6° 43"N and Longitude 1° 36" N within the rainfall forest zone of Ghana with an average rainfall of 645mm during the period of the studies. The mean minimum and maximum temperatures are $22^{0}C$ and $31^{0}C$, respectively, with the mean relative humidity of 85.75%.

3.2 SOURCES OF EXPERIMENTAL MATERIALS

Seeds of three tomato cultivars Cal. J (exotic), Power (local) and Royal (exotic), inorganic fertilizers 'Asasewura' cocoa fertilizer (NPK 0-22-18 +9CaO+6S+$5MgO_{(s)}$) Sulphate of Ammonia (21%N+ 24S) and NPK (15-15 -15 + 2MgO +3Zn), an organophosphate insecticide, Cypadem (43.6% EC,36g of cypamethrin + 400g of dimethoate per litre) and fungicide Sundomil (72% WP, 8% metalaxyl + 64% mancozeb) were obtained from local agro chemical shops in Kumasi. Poultry manure was obtained from the Animal Science Department poultry farm at KNUST.

3.3 FIELD ESTABLISHMENT AND EXPERIMENTAL DESIGN

Seeds of tomato cultivars (Cal J., Power and Royal) were nursed on nursery beds of about 15-20cm in height and pricked out 7 days later onto a seedbed. The experimental field was ploughed and harrowed and planned into a 3 x 4 factorial in a Randomized Complete Block Design involving three (3) cultivars and four (4) soil amendments treatment with three (3) replications. Soil samples were randomly collected from different cores at 0-15cm and 15-30cm for analysis before and from 0-30cm core after the studies for organic carbon (OC), organic matter (OM), total nitrogen (N), exchangeable Potassium (K), Sodium (Na), Calcium (Ca), Magnesium (Mg), Available Phosphorus and pH at the KNUST Soil Science laboratory.

Seedlings were transplanted three weeks later onto the experiment field which had been lined and pegged using a plot size of 3m x 4m and planting distances of 60cm x 75cm between and within rows and 90 centimeters between plots.

3.4 CULTURAL PRACTICES AND AGROCHEMICAL RATES USED

All appropriate cultural practices including pricking, weeding, and watering, staking, pests control were timely performed. Partially decomposed poultry manure was applied at 1.1 Kg/m^2 at three weeks before seedling were transplanted. NPK (15-15-15+2MgO+3Zn) was applied as basal fertilizer at 5 grames per plant two weeks after seedlings were transplanted on plots designated for 'Asasewura', cocoa fertilizer (NPK 0-22-18 +9CaO+6s+5MgO(s) and Sulphate of Ammonia (21% N+ 24S) application. 'Asasewura', cocoa fertilizer (NPK 0-22-18 +9CaO+6s+5MgO(s) and Sulphate of

Ammonia (21% N+ 24S) were applied at 5 grames and 3 grames per plants respectively at two weeks after NPK (15-15-15+2MgO+3Zn) application.

There were weekly sprayings of insecticides - Cypadem (43.6% EC), an organophosphate insecticide containing 36g cypamethrin plus 400g dimethoate per litre in the form of emulsifiatible concentrate at dosage rate of 0.6-1 litre/ha. Fungicides sundomil (72% WP) containing metalaxyl 8% and mancozeb 64% per kilogram in the form of wettable powder at 250-350g per 100 litres of water was sprayed at 10-14 days intervals to control insects.

3.5 HARVESTING AND POST HARVEST OPERATIONS

Fruits were harvested by hand, at the pink stage (calyx attached) every other day in the mornings within six weeks, from each plot and immediately placed under shade to maintain fruits temperature. Fruits were quickly transported to the laboratory and sorted out to eliminate bruised, punctured and damage ones. Fruits were graded for uniform colour and size for further studies on qualitative parameters.

3.6 FRUIT QUALITY ANALYSIS

Thirty six (36) pots containing ten (10) fruits from each plot were set up in the laboratory for each harvest in complete randomized design and stored for 7 days at average temperature of 26.85°C and relative humidity of 85.75%.

3.6. DATA COLLECTED

3.6.1 Weight Loss (WL)

Fruits were weighed daily for seven days and the difference in weight loss expressed as a percentage of weight loss from the initial weight of five fruits sample.

3.6.2 Fruit Firmness (FF)

Fruit firmness was determined with a fruit firmness tester (Effegi type Bishop FT 237). A circular portion of the peel of diameter of about 2 cm of each of the five fruits from each plot was removed before applying the plunger of the firmness tester in order to eliminate the effect due to the peel; and firmness was expressed in Newton (Batu, 1998).

3.6.3 General Appearance (GA)

Fruit general appearance was scored by overall rating that included freshness (green calyx), decay, firmness, defects, colour on a scale of 1-5 with: 0-1= Poor, 2-3= Good and 4-5= Very good.

3.6.4 Membrane Ion Leakage (MIL)

Membrane ion leakage of fruit was determined using the method of Knowles, *et al*. (2001) with some modifications. Ten (10) discs (10 mm in diameter) per cultivar were incubated in 20ml distilled deionized water at 5, 10, 15, 30 and 60 minutes intervals and conductivity measured and expressed as a percentage of the total electrolytes. Total electrolyte was also determined by freezing samples for 24 hours after taking all readings (5-60minutes). Samples were then thawed and boiled for 20 minutes and conductivity measured. Conductivity meter (Hanna instrument) was used to measure membrane ion leakage.

3.6.5 Fruit Decay (FD)

Decay of fruit was recorded as soon as fungal mycelia appeared on the calyx or peel of the fruit. Decay was expressed as a percentage of the total initial fruit number stored.

3.6.6 Pericarp Thickness (PTK)

High precision digital veneer caliper was used to measure pericarp thickness (mm) from three (3) discs of 10 mm in diameter taken at the equatorial region of five fruits.

3.6.7 Pericarp Weight (PWT)

Analytical scale was used to measure pericarp weight (g) of three (3) discs of 10 mm in diameter taken at the equatorial region of five fruits.

3.6.8 Dry matter (DM)

Dry matter content of fruits was measured by taking three (3) discs of 10 mm in diameter from the equatorial region of each of five fruits and oven dried at 105 degree Celsius till constant dry weight was recorded according to AOAC (1990) and weight expressed in gram (g).

3.6.9 Moisture Content (MC)

Moisture content of fruits was determined by desiccation of three (3) discs of 10 mm in diameter at the equatorial region of five fruits from each plot at 105ºC for 24h. The difference between the fresh weight and dry weight was expressed as a percentage of the initial fresh weight of the three (3) discs at the equatorial region of five fruits (AOAC, 1990).

3.6.10 Total Soluble Solids (TSS)

Total soluble solid was determined in the same five fruits tested for fruit firmness, by squeezing out juice from fruits on Abbe's hand held refractometer and reflections measured in % Brix. AOAC, 1984.

3.6.11 Shelf life (SL)

The shelf life was determined from the starts of harvesting and extended up to the start of rotting of fruits (Mondal, 2000).

3.7. Data Analysis

Data collected was subjected to statistical analysis using GENSTAT Discovery Edition 3.0 Analytical Software. Means were separated by Lsd test at 5% and Correlation analysis was performed at 1% and 5% using Statistical Package for Social Science Students (SPSS) edition 18.

CHARPTER FOUR

4.0 RESULTS

4.1 WEIGHT LOSS

Three tomato cultivars Cal. J (exotic) Royal (exotic) and Power (local) of different fruit sizes, stored for 7 days at 26.85ºC and 85.75% RH were evaluated for postharvest weight loss. The analysis of variance indicated significant differences ($P < 0.001$) among cultivars in fruit weight loss. Royal fruits recorded the lowest weight loss (2.57g) followed by fruits harvested from cultivars Cal. J (3.33g) and Power (3.56g). However, weight loss observed between Power and Cal. J fruits indicated no significant differences (Table 1).

Tomato fruits from fields amended with NPK plus ‘Asasewura’ cocoa fertilizer, NPK plus Sulphate of ammonia, Poultry manure and the Control (no amendment), stored for 7 days at 26.85ºC and 85.75% RH and assessed for the influence of soil amendment types on the postharvest performance in fruit weight loss. The analysis of variance indicated significant differences ($P = 0.002$) among soil amendment types in fruit weight loss. Relatively low weight loss was recorded by fruits harvested from fields amended with NPK plus ‘Asasewura’ cocoa fertilizer (2.68g) while high weight loss was recorded by fruits harvested from Control (3.27g) and fields amended with NPK plus Sulphate of ammonia (3.30g) and Poultry manure (3.36g). No significant differences ($P = 0.05$) in weight loss were observed among fruits harvested from fields amended with Poultry manure, NPK plus Sulphate of ammonia and Control (no amendment) (Table 2).

Table 1: Means of Tomato fruit Weight loss (WL) of three tomato cultivars after seven days storage at 26.85ºC and 85.75% RH.

CULTIVARS	WEIGHT LOSS (g)
Cal J	3.33a
Power	3.56a
Royal	2.57b
CV %	4.9

**values followed by the same letters are not significantly different at P < 0.05*

Table 2: Means of fruit Weight loss (WL) of tomato Fruits harvested from four different soil amendment after seven days storage at 26.85ºC and 85.75% RH.

SOIL AMENDMENTS	WEIGHT LOSS (g)
NPK + ASASEWURA COCOA FERTILIZER	2.68b
NPK+ SULPHATE OF AMMONIA	3.30a
POULTRY MANURE	3.36a
CONTROL	3.27a
CV %	4.9

**values followed by the same letters are not significantly different at P < 0.05*

No significant differences (P>0.05) were observed among the interaction of cultivar types and soil amendment types in fruit weight loss (Appendix Table 1.1).

4.2. FRUIT FIRMNESS

Fruits firmness of three tomato cultivars was measured after 7 days storage at 26.85ºC and 85.75% RH. The analysis of variance on fruit firmness showed highly significant differences ($P < 0.001$) among the cultivar types. Fruits harvested from Royal recorded the highest firmness (3.42 N) followed by Cal. J (2.99 N) and Power (2.53 N) (Table 3).

Influence of different soil amendment types on tomato fruits firmness was measured after 7 days storage at 26.85ºC and 85.75% RH. The analysis of variance indicated highly significant difference ($P < 0.001$) in fruit firmness among the soil amendment types. The highest firmness was recorded by fruits harvested from fields amended with NPK plus 'Asasewura' cocoa fertilizer (3.31N) followed by the Control (3.11N), Poultry manure (2.91N) and NPK plus Sulphate of ammonia (2.80N). However, no significant differences were observed between fruits harvested from fields amended with NPK + 'Asasewura' cocoa fertilizer (3.31N) and Control (3.11N) as well as NPK plus Sulphate of ammonia and Poultry manure. There was also no significant difference in fruit firmness between Control (3.11N) and Poultry manure (2.91N) (Table 4).

Table 3: Means of Tomato Fruit Firmness (FF) from three cultivars after seven days storage at 26.85ºC and 85.75% RH.

CULTIVARS	FRUIT FIRMNESS (N)
Cal J	2.99b
Power	2.69c
Royal	3.41a
CV %	2.0

**values followed by the same letters are not significantly different at P < 0.05*

Table 4: Means of Tomato Fruit Firmness (FF) from four different soil amendment types after seven days storage at 26.85ºC and 85.75% RH.

SOIL AMENDMENTS	FRUIT FIRMNESS (N)
NPK + ASASEWURA COCOA FERTILIZER	3.31a
NPK+ SULPHATE OF AMMONIA	2.80c
POULTRY MANURE	2.91bc
CONTROL	3.11ab
CV %	2.0

**values followed by the same letters are not significantly different at P < 0.05*

The analysis of variance indicated no significant differences between the interaction of cultivar types and soil amendment types in fruit firmness after 7 days storage at 26.85ºC and 85.75% RH (Appendix Table 1.2).

4.3. GENERAL APPEARANCE

Fruits assessed for general appearance after 7 days storage at 26.85ºC and 85.75% RH indicated significant differences ($P < 0.001$) among cultivar types. Royal fruits (4.03) recorded the best in general appearance followed by Cal J. (3.38) and Power (3.32). However, no significant difference was obtained in fruit general appearance between Power and Cal. J (Table 5).

The analysis of variance on the effect of soil amendment types on fruit general appearance indicated significant differences ($P = 0.001$). Fruits harvested from NPK plus 'Asasewura', cocoa fertilizer amended fields (3.93) and Poultry manure fields amended fields (3.87) had relatively better general appearance than fruits harvested from fields amended with NPK plus Sulphate of ammonia (3.44) and Control (no amendment) (3.07). However, no significant differences were observed between fruits harvested from fields amended with NPK plus 'Asasewura', cocoa fertilizer (3.93) and Poultry manure (3.87) and also between NPK plus Sulphate of ammonia (3.44) amended fields and Control fields (3.07) (Table 6).

Table 5: Means of Tomato fruit General Appearance (GA) from three cultivars after seven days storage at 26.85ºC and 85.75% RH.

CULTIVARS	GENERAL APPEARANCE (rated:1-5)
Cal J	3.38b
Power	3.31b
Royal	4.03a
CV %	2.8

**values followed by the same letters are not significantly different at P < 0.05*

Table 6: Means of Tomato fruit General Appearance (GA) from four different soil amendments after seven days storage at 26.85ºC and 85.75% RH.

SOIL AMENDMENTS	GENERAL APPEARANCE (rated:1-5)
NPK + ASASEWURA COCOA FERTILIZER	3.93a
NPK+ SULPHATE OF AMMONIA	3.44b
POULTRY MANURE	3.87a
CONTROL	3.07c
CV %	2.8

**values not connected by the same letters are significantly different at P < 0.05*

No significant differences were observed between the interaction of cultivar types and soil amendment types in fruit general appearance after 7 days storage at 26.85ºC and 85.75% RH (Appendix Table 1.3).

4.4 MEMBRANE ION LEAKAGE (%EC)

Three tomato cultivars Cal. J, Royal and Power of different fruit sizes, stored for 7 days at 26.85ºC and 85.75% RH were evaluated for postharvest membrane ion leakages. Analysis of variance indicated highly significant differences ($P < 0.001$) among the cultivars types. Power fruits recorded the highest membrane ion leakage (15.49%) compared to fruits of Cal. J (13.91%) and Royal (12.30%) (Table7).

The analysis of variance indicated significant differences ($P = 0.001$) among fruits harvested from different soil amendment types in membrane ion leakage. Comparatively, high membrane ion leakage was recorded in fruits harvested from fields amended with Poultry manure (14.61%), NPK plus Sulphate of ammonia (13.87%) and Control (14.61%), while low membrane ion leakage was recorded from fruit harvested from field amended with NPK plus 'Asasewura' cocoa fertilizer (12.52%). No significant differences ($P>0.05$) were observed among fruits harvested from the Control (14.61%) and fields amended with Poultry manure (14.61 %) and NPK plus Sulphate of ammonia in membrane ion leakage (Table 8).

Table 7: Means of fruit membrane ion leakage of three tomato cultivars after seven days storage at 26.85ºC and 85.75% RH.

CULTIVARS	MEMBRANE ION LEAKAG (%EC)
Cal J	13.91b
Power	15.49a
Royal	12.30c
CV %	4.8

**values followed by the same letters are not significantly different at P < 0.05*

Table 8: Means of membrane ion leakage of tomato Fruits harvested from four different soil amendment after seven days storage at 26.85ºC and 85.75% RH.

SOIL AMENDMENTS	MEMBRANE ION LEAKAGE (%EC)
NPK + ASASEWURA COCOA FERTILIZER	12.52b
NPK+ SULPHATE OF AMMONIA	13.87a
POULTRY MANURE	14.61a
CONTROL	14.61a
CV %	4.8

**values not connected by the same letters are significantly different at P < 0.05*

The analysis of variance indicated no significant differences among the interactions of cultivars and soil amendment types in membrane ion leakage after 7 days storage at 26.85ºC and 85.75% RH (Appendix Table 1.4).

4.5 PERICARP THICKNESS

Pericarp thickness of fruits of three tomato cultivars, stored at 26.85ºC and 85.75% RH for seven days was measured. The analysis of variance indicated highly significant differences ($P < 0.001$) among the cultivars. Royal fruits had the thickest pericarp (3.74 mm) followed by fruits of Power (3.05mm) and Cal. J (2.83 mm) (Table 9).

Tomato fruits harvested from the different soil amended fields were evaluated to determine the influence of soil amendment types on fruit pericarp thickness. The analysis of variance indicated highly significant variations ($P < 0.001$) among the soil amendment types. Fruits harvested from fields amended with Poultry manure (3.88 mm), NPK plus Sulphate of ammonia (3.69 mm) and NPK plus 'Asasewura' cocoa fertilizer (3.36 mm) recorded higher pericarp thickness than fruits harvested from the Control fields (2.86 mm) (Table 10).

Table 9: Means of Tomato fruit Pericarp Thickness from three cultivars after seven days storage at 26.85ºC and 85.75% RH.

CULTIVARS	PERICARP THICKNESS (mm)
Cal J	2.83c
Power	3.05b
Royal	3.74a
CV %	4.6

**values followed by the same letters are not significantly different at P < 0.05*

Table 10: Means of Tomato fruit Pericarp Thickness from four different soil amendments after seven days storage at 26.85ºC and 85.75% RH.

SOIL AMENDMENTS	PERICARP THICKNESS (mm)
NPK + ASASEWURA COCOA FERTILIZER	3.36b
NPK+ SULPHATE OF AMMONIA	3.09c
POULTRY MANURE	3.65a
CONTROL	2.74d
CV %	4.6

**values followed by the same letters are not significantly different at P < 0.05*

Fruits of three tomato cultivars harvested from four different soil amendment fields, stored for seven days at 26.85ºC and 85.75% RH were evaluated for post harvest pericarp thickness. The analysis of variance indicated significant differences ($P < 0.019$) among interactions of cultivar types and soil amendment types in fruit pericarp thickness.

Relatively, thick pericarp was also observed for the interaction of cultivars, Cal .J, Power, Royal and fields amended with Poultry manure (3.00 mm, 3.68 mm and 4.26 mm) respectively. Relatively thin pericarp was observed at the interaction of cultivars Cal .J, Power, Royal and Control (2.37 mm, 2.57 mm and 3.27 mm), respectively (Table 11).

No significant differences (P > 0.05) were observed among fruits of Cal. J harvested from fields amended with Poultry manure (3.00 mm), NPK plus 'Asasewura', cocoa (2.99 mm) and NPK plus Sulphate of ammonia (2.96 mm) as well as between fruits of Power harvested from NPK plus Sulphate of ammonia fields (2.64 mm) and those harvested from Control fields (2.57 mm) in pericarp thickness (Table 11).

Table 11: Means of Tomato fruit pericarp thickness (mm) from the interactions of different soil amendments and cultivar types after seven days storage at 26.85ºC and 85.75% RH

	AMENDMENTS				
CULTIVARS	NPK+CA	NPK+SA	PM	CONT	*Means*
Cal. J.	2.99e	2.96e	3.00e	2.37g	*2.83*
Power	3.32d	2.64f	3.68c	2.57f	*3.05*
Royal	3.77b	3.67c	4.26a	3.27d	*3.74*
Means	*3.36*	*3.09*	*3.65*	*2.74*	
CV%				4.8	

**values followed by the same letters are not significantly different at P < 0.05*

The interactions of cultivars and soils amended with NPK plus 'Asasewura', cocoa fertilizer indicated significant differences in pericarp thickness. The thickest pericarp was recorded for the interactions of soils amended NPK plus 'Asasewura', cocoa fertilizer and Royal (3.77mm) followed by Power (3.32mm) and Cal. J (2.99mm) (Table 11).

Fields amend with NPK plus Sulphate of ammonia increased pericarp thickness in Royal fruits (3.67 mm) than Power (2.96 mm) and Cal. J (2.64 mm). However, no significant differences were observed in pericarp thickness between the interactions of Power, Cal. J and fields amended with NPK plus Sulphate of ammonia respectively. The interactions of poultry manure amended fields and Royal recorded the largest pericarp thickness (4.26 mm) followed by cultivars Cal J (3.68 mm) and Power (3.00) (Table 11). Overall, royal had the thickest pericarp (3.74mm) while poultry manure amend fields produced the thickest pericarp (3.65mm)

4.6 FRUIT DECAY

Fruits of the three cultivars, stored for 7 days at 26.85ºC and 85.75% RH were evaluated for postharvest decay. The analysis of variance indicated highly significant difference ($P < 001$) among the cultivars. Power fruits recorded the highest decay incidence (11.70%) followed by Cal. J (8.70%) and Royal (6.00%). However, no significant difference ($P > 0.05$) was observed in fruit decay between Cal. J (8.70) and Royal (6.00) (Table 12).

Influence of soil amendment types on postharvest decay of tomato was assessed for fruits harvested from the four different amended fields after 7 days' storage at 26.85ºC and 85.75% RH. The analysis of variance showed significant difference ($P = 0.038$) in fruit decay among the soil amendments. Fruits harvested from control (no amendment), poultry manure and NPK plus Sulphate of ammonia fields' recorded relatively high percentages in fruit decay (10.40%, 9.20% and 8.80% respectively) while relatively low percentage decay (6.80%) was observed from fields amended with NPK plus 'Asasewura', cocoa fertilizer. However, no significant differences (P > 0.05) were observed among fruits harvested from control (10.40 %), poultry manure (9.20 %) and NPK plus Sulphate of ammonia (8.80 %) (Table 13).

Table 12: Means of Tomato fruit Decay of three tomato cultivars after seven days storage at 26.85ºC and 85.75% RH.

CULTIVARS	FRUIT DECAY (%)
Cal J	8.70b
Power	11.70a
Royal	6.00b
CV %	16.1

**values followed by the same letters are not significantly different at P < 0.05*

Table 13: Means of Tomato fruit Decay from four different soil amendment after seven days storage at 26.85ºC and 85.75% RH.

SOIL AMENDMENTS	FRUIT DECAY (%)
NPK + ASASEWURA COCOA FERTILIZER	6.80b
NPK+ SULPHATE OF AMMONIA	8.80ab
POULTRY MANURE	9.20a
CONTROL	10.40a
CV %	16.1

**values followed by the same letters are not significantly different at P < 0.05*

The analysis of variance indicated no significant differences (P > 0.05) between the interactions of cultivar types and soil amendment types in fruit decay after 7 days storage at 26.85ºC and 85.75% RH (Appendix Table 1.6).

4.7 PERICARP WEIGHT

Pericarp weight of the three cultivars, stored for 7 days at 26.85ºC and 85.75% RH, were evaluated to determine differences among the cultivars. The analysis of variance in fruit pericarp weight indicated highly significant differences (P < 0.001) among the cultivars. Power fruits recorded the heaviest pericarp weight (3.76g) followed by fruits harvested from Royal (3.67g) and Cal J (3.08g). However, no significant difference (P > 0.05) was observed between fruits of Power and Royal in pericarp weight (Table 14).

The analysis of variance indicated highly significant differences (P = 001) among the soil amendment types in fruit pericarp weight. Fruits harvested from Poultry manure amended fields recorded relatively higher pericarp weight (4.13g) while relatively low pericarp weight were recorded for fruits harvested from fields amendment with NPK plus Sulphate of ammonia (3.59g), NPK plus 'Asasewura' cocoa fertilizer(3.47g) and Control (2.83g). Nevertheless, no significant variation was indicated between fruits harvested from NPK plus Sulphate of ammonia and NPK plus 'Asasewura' cocoa fertilizer in fruit pericarp weight (Table 15).

Table 14: Means of Tomato fruit Pericarp Weight from three tomato cultivars after seven days storage at 26.85ºC and 85.75% RH.

CULTIVARS	PERICARP WEIGHT (g)
Cal J	3.08b
Power	3.76a
Royal	3.67a
CV %	1.1

**values followed by the same letters are not significantly different at P < 0.05*

Table 15: Means of Tomato fruit Pericarp Weight from four different soil amendment after seven days storage at 26.85ºC and 85.75% RH.

SOIL AMENDMENTS	PERICARP WEIGHT (g)
NPK + ASASEWURA COCOA FERTILIZER	3.47b
NPK+ SULPHATE OF AMMONIA	3.59b
POULTRY MANURE	4.13a
CONTROL	2.83c
CV %	1.1

**values followed by the same letters are not significantly different at P < 0.05*

The analysis of variance indicated no significant differences (P > 0.05) among interactions of cultivars types and soil amendment types in fruit pericarp weight. (Appendices Table 1.7)

4.8 DRY MATTER

Dry matter content of the three tomato cultivars stored at 26.85ºC and 85.75% RH were assessed to establish differences in dry matter content. The analysis of variance showed significantly high differences (P = 0.001) in dry matter content among the cultivars. Royal fruits recorded the highest dry matter content of 0.35g followed by fruits from Power (0.28g) and Cal J (0.27g). However, no significant difference (P > 0.05) was observed between fruits harvested from Power (0.28g) and Cal J (0.27g) (Table 16).

After 7 days storage at 26.85ºC and 85.75% RH, the analysis of variance showed significant difference (P=0.002) in dry matter content among fruits harvested for the different soil amendments. Relatively high dry matter were recorded from fruits harvested from fields amended with NPK plus 'Asasewura' cocoa fertilizer (0.33g) and NPK plus Sulphate of ammonia (0.32g) while relatively low dry matter content of 0.28g and 0.25g were recorded for those harvested from fields amended with Poultry manure and Control, respectively. No significant differences (P > 0.05) were observed in fruit dry matter between fruits harvested from fields amended with NPK plus 'Asasewura' cocoa fertilizer and NPK plus Sulphate of ammonia (Table 17).

Table 16: Means of fruit Dry Matter of three tomato cultivars after seven days storage at 26.85ºC and 85.75% RH.

CULTIVARS	DRY MATTER (g)
Cal J	0.27b
Power	0.28b
Royal	0.35a
CV %	4.1

**values followed by the same letters are not significantly different at P < 0.05*

Table 17: Means of Tomato fruit Dry Matter from four different soil amendments after seven days storage at 26.85ºC and 85.75% RH.

SOIL AMENDMENTS	DRY MATTER (g)
NPK + ASASEWURA COCOA FERTILIZER	0.33a
NPK+ SULPHATE OF AMMONIA	0.32a
POULTRY MANURE	0.29b
CONTROL	0.25c
CV %	4.1

**values followed by the same letters are not significantly different at P < 0.05*

The interactions of cultivar types and soil amendment types in tomato fruit dry matter content after 7 days storage at 26.85ºC and 85.75 % RH in this study showed no significant differences (P > 0.05) among the means (Appendices Table 1.8).

4.9 MOISTURE CONTENT

There were significant differences (P=0.001) among the cultivars in fruit moisture content after 7 days storage at 26.85ºC and 85.75% RH. Power fruits recorded the highest percentage moisture content (92.51%) followed by Cal. J fruits (91.12%) and Royal fruits (90.42%). However, no significant differences (P > 0.05) were observed between Cal. J and Royal fruits in moisture content (Table 18).

Moisture content of fruits harvested from different amended fields stored for 7 days at 26.85ºC and 85.75% RH was measured to determine differences as influenced by the soil amendment types. The analysis of variance indicated highly significant difference ($P < 0.001$) in moisture content among fruits harvested from the different soil amendments. Fruits harvested from Poultry manure amended fields recorded the highest moisture content (92.93%) followed by fruits harvested from NPK plus Sulphate of ammonia amended fields (91.05%), Control (90.96%) and NPK plus 'Asasewura' cocoa fertilizer amended fields (90.46%). No significant differences ($P > 0.05$) in fruit moisture content were observed among fruits harvested from NPK plus 'Asasewura' cocoa fertilizer, NPK plus Sulphate of ammonia amended fields and Control (no soil amendment) (Table 19).

Table 18: Means of Tomato fruit Moisture Content from three tomato cultivars after seven days storage at 26.85ºC and 85.75% RH.

CULTIVARS	MOISTURE CONTENT (%)
Cal J	91.12b
Power	92.51a
Royal	90.42b
CV %	0.4

**values followed by the same letters are not significantly different at $P < 0.05$*

Table 19: Means of Tomato fruit Moisture Content from four different soil amendments after seven days storage at 26.85ºC and 85.75% RH.

SOIL AMENDMENTS	MOISTURE CONTENT (%)
NPK + ASASEWURA COCOA FERTILIZER	90.46b
NPK+ SULPHATE OF AMMONIA	91.05b
POULTRY MANURE	92.93a
CONTROL	90.96b
CV %	0.4

**values followed by the same letters are not significantly different at P < 0.05*

The analysis of variance showed no significant difference (P > 0.05) between the interactions of cultivar types and soil amendment types in fruit moisture content after 7 days storage at 26.85ºC and 85.75% RH (Appendices Table 1.9).

4.10 TOTAL SOLUBLE SOLIDS

Total soluble solids of the three cultivar types, stored for 7 days at 26.85ºC and 85.75% RH was evaluated to determine whether any differences existed among the total soluble solids of the cultivars. The analysis of variance indicated highly significant differences (P < 0.001) among the cultivars. Royal fruits recorded the highest total soluble solids (4.17 % Brix) followed by fruits of Power (3.73 % Brix) and Cal. J (3.65% Brix). However, no significant difference was observed between Power fruits (3.73% Brix) and Cal. J fruits (3.65% Brix) with regard to fruit total soluble solids (Table 20).

Soil amendment significantly ($P < 0.001$) affected fruit total soluble solids. Relatively high total soluble solids were recorded for fruits harvested from NPK plus 'Asasewura' cocoa fertilizer (4.04% Brix) and Poultry manure(4.02% Brix) amended fields while relatively low total soluble solids were recorded for fruits harvested from fields amended with NPK plus Sulphate of ammonia (3.91% Brix) and Control (3.42% Brix). No significant differences ($P > 0.05$) were observed between fruits harvested from NPK plus 'Asasewura' cocoa fertilizer, Poultry manure and NPK plus Sulphate of ammonia (Table 21).

Table 20: Means of Tomato fruit Total Soluble solids from tree cultivars after seven days storage at 26.85ºC and 85.75% RH.

CULTIVARS	TOTAL SOLUBLE SOLIDS (%Brix)
Cal J	3.65b
Power	3.73b
Royal	4.17a
CV %	1.5

**values followed by the same letters are not significantly different at $P < 0.05$*

Table 21: Means of Tomato fruit Total Soluble solids from four different soil amendment after seven days storage at 26.85ºC and 85.75% RH.

SOIL AMENDMENTS	TOTAL SOLUBLE SOLIDS (%Brix)
NPK + ASASEWURA COCOA FERTILIZER	4.04a
NPK+ SULPHATE OF AMMONIA	3.91a
POULTRY MANURE	4.02a
CONTROL	3.42b
CV %	1.5

**values followed by the same letters are not significantly different at $P < 0.05$*

The analysis of variance indicated significant difference ($P < 0.016$) between cultivars and soil amendment interaction in total soluble solids. No significant differences ($P > 0.05$) were observed between the interaction of Cal J and NPK plus 'Asasewura' cocoa fertilizer; poultry manure amended fields and Control fields as well as the interaction of Cal J and NPK plus 'Asasewura' cocoa fertilizer and Poultry manure amended fields in fruits total soluble solids (Table 22).

Comparatively, high total soluble solids were observed the interactions of Power and soils amended with Poultry manure (4.00 % Brix) and NPK plus 'Asasewura' cocoa fertilizer (3.91 % Brix) while relatively low total soluble were observed in the interaction of Power and NPK plus Sulphate of ammonia (3.66% Brix) and Control (3.35 % Brix) amended field. However, no significant differences ($P > 0.05$) were observed among the interactions of fields amended with NPK plus ‘Asasewura’ cocoa fertilizer, NPK plus Sulphate of ammonia and Power respectively in fruits’ total soluble solids (Table 22).

Table 22: Means of Tomato total soluble solids from the interaction of cultivar types and soil amendment types after seven days storage at 26.85ºC and 85.75% RH

	AMENDMENTS				
CULTIVARS	NPK+CA	NPK+SA	PM	CONT	*Means*
Cal. J.	3.70cd	3.84c	3.65cd	3.42d	*3.65*
Power	3.91bc	3.66c	4.00b	3.35d	*3.73*
Royal	4.52a	4.24a	4.42a	3.49d	*4.17*
Means	*4.04*	*3.91*	*4.02*	*3.42*	
CV%					1.5

**values followed by the same letters are not significantly different at P < 0.05*

The interactions of cultivar Royal and fields amended with NPK plus ‘Asasewura’ cocoa fertilizer (4.52% Brix), Poultry manure (4.42% Brix) and NPK plus Sulphate of ammonia (4.24%) increased fruit total soluble solids over the interactions of Royal and Control (3.49% Brix) fields. No significant differences (P > 0.05) were observed among the interactions of Royal and fields amended with NPK plus ‘Asasewura’ cocoa fertilizer, Poultry manure and NPK plus Sulphate of ammonia in fruit total soluble solids as well as between the interactions of Power, Cal. J and fields amended with NPK plus ‘Asasewura’ cocoa fertilizer (Table 22).

Significant differences ($P < 0.05$) were observed among the interactions of the tomato cultivars and fields amended with Poultry manure. The highest total soluble solids were recorded in the interactions of Royal and fields amended with Poultry manure in total soluble (4.42% Brix) solids followed for the interactions of Power and Cal. J with fields amended with Poultry manure at 4.00% Brix and 3.65 % Brix respectively (Table 22).

Total soluble solids of the interactions of cultivars and field amended with NPK plus Sulphate of ammonia indicated significant differences. The highest total soluble solids was recorded by the interactions of Royal and fields amended with NPK plus Sulphate of ammonia (4.24% Brix). Power and Cal. J and fields amended with NPK plus Sulphate of ammonia at 3.84% Brix and 3.66% Brix respectively. No significant difference ($P > 0.05$) was however observed between the interaction of Power, Cal. J and fields amended with NPK plus Sulphate of ammonia in total soluble solids (Table 22).

No significant differences ($P > 0.05$) were observed among the interactions of Royal, Power, Cal. J and Control fields (Table 22).

4.11 SHELF LIFE

The three tomato cultivars, Cal J, Power and Royal fruits were stored at 26ºC and 85.75% RH and evaluated for fruits shelf life. The analysis of variance indicated significant differences ($P < 0.001$) in fruits shelf life among the cultivars. Royal fruits (10.3 days) recorded significantly the longest shelf life followed by Cal J (7.93 days) and Power (6.7 days) fruits (Table 23).

The analysis of variance showed significant differences ($P < 0.002$) in fruits shelf life among the soil amendments. Fruits harvested from NPK plus 'Asasewura' cocoa fertilizer amended fields recorded the highest shelf life (9.4 days) followed by fruits harvested from fields amended with Poultry manure (8.3days), NPK plus Sulphate of ammonia (7.9 days) and Control (7.6 days) fields. No significant differences ($P > 0.05$) in fruits shelf life were observed between fruits harvested from fields amended with Poultry manure, NPK plus Sulphate of ammonia and Control (Table 24).

Table 23: Means of Tomato fruit Shelf Life from three cultivars after seven days storage at 26.85ºC and 85.75% RH.

CULTIVARS	SHELF LIFE (days)
Cal J	7.93b
Power	6.68c
Royal	10.29a
CV %	3.1

*****values followed by the same letters are not significantly different at $P < 0.05$*

Table 24: Means of Tomato fruit Shelf Life from four different soil amendments after seven days storage at 26.85ºC and 85.75% RH.

SOIL AMENDMENTS	SHELF LIFE (days)
NPK + ASASEWURA COCOA FERTILIZER	9.39a
NPK+ SULPHATE OF AMMONIA	7.58b
POULTRY MANURE	8.32b
CONTROL	7.92b
CV %	3.1

**values followed by the same letters are not significantly different at P < 0.05*

The analysis of variance indicated no significant differences (P > 0.05) between the interactions of cultivar types and soil amendment types in fruit Shelf Life evaluated after 7 days storage at 26.85ºC and 85.75% RH. (Appendix Table 1.11)

4.12 CORRELATION OF TOMATO FRUITS QUALITY TRAITS

The relationship among tomato fruit quality parameters after storage at 26ºC and 85.75%RH were examined to determine their significant associations. The relationship indicated that, higher weight loss resulted in lower fruit firmness and fruit shelf life as well as higher fruit decay and membrane ion leakage (Table 25). Fruit weight loss indicated significantly high and negative correlation (P < 0.01) between fruit firmness (-0.71) and shelf life (-0.71) but a high positive correlation between membrane ion leakage (0.63) and fruit decay (0.57). However, no significant correlations (P > 0.01) were observed between fruit weight loss and fruit moisture content as well as fruit pericarp weight (Table 25).

The association among fruits firmness, decay, moisture content and shelf life indicated that, the higher the fruit firmness, the lower the fruit decay and fruit moisture content but the higher the fruit shelf life (Table 25). High but negative significant correlation ($P < 0.01$) was observed between fruits firmness and fruit decay (-0.60) and fruit moisture content (-0.62). However, fruit firmness indicated positive significant correlation ($P < 0.01$) with fruits shelf life (0.73).

Increase in fruit general appearance is directly proportional to increase in fruit pericarp thickness and fruit shelf life. General appearance indicated positive significant correlation between fruit pericarp thickness (0.69) at $P < 0.05$, and shelf life (0.55) at $P < 0.01$ (Table 25).

High membrane ion leakage is directly proportional to high fruit decay and water loss but indirectly proportional to fruit shelf life and pericarp weight. Membrane ion leakage indicated high and positive significant correlation ($P < 0.01$) between fruit decay (0.61) and fruit weight loss (0.63), respectively. However, membrane ion leakage showed negative but significant correlation between shelf life (-0.67) and pericarp thickness (-0.38 at $P < 0.05$) respectively (Table 25).

Examination of the relationship between pericarp thickness and other postharvest qualities of tomato fruits showed that, the higher the fruit pericarp thickness the higher the pericarp weight, dry matter, total soluble solids and shelf life. Fruit pericarp thickness indicated significantly high positive correlation ($P < 0.01$) with fruit pericarp weight

(0.68), dry matter (0.65), total soluble solids (0.73) and shelf life (0.62) respectively (Table 25).

Fruit pericarp weight indicated high and positive correlation with total soluble solids (0.63) (Table 25).

The association between fruit moisture content and fruit dry matter as well as fruit firmness indicated that, the higher the fruit moisture content the higher the firmness, but the lower the fruit dry matter. Fruit moisture content indicated negative but significant correlation ($P < 0.01$) between fruit dry matter (-0.80) and fruit firmness (-0.62) respectively (Table 25).

Table 25. Correlation values and P values between postharvest quality traits of tomato fruits after 7 days Storage at 26.85ºC and 85.75%RH

	WTL	FF	GA	MIL	PTK	FD	PWT	DM	MC	TSS
WTL										
FF	-0.71**									
GA	-0.44**	0.39*								
MIL	0.63**	-0.57**	-0.42*							
PTK	-0.46**	0.41*	0.69**	-0.38*						
FD	0.57**	-0.60**	-0.40*	0.61**	-0.46**					
PWT	0.03NS	0.13NS	0.39*	0.02NS	0.68**	0.14NS				
DM	-0.36*	0.55**	0.54**	0.28NS	0.65**	0.33NS	0.39*			
MC	0.31NS	-0.62**	-0.28	0.24NS	0.22NS	0.23NS	0.23NS	0.80*		
TSS	-0.48**	0.27NS	0.60**	-0.55**	0.73**	-0.40**	0.63**	0.37*	0.05NS	
SL	-0.71**	0.73**	0.55**	-0.67**	0.62**	-0.63**	0.16NS	0.48*	-0.34*	0.67**

Weight Loss (WTL), Fruit Firmness (FF), General Appearance (GA,) and Membrane Ion Leakage (MIL), Fruit Pericarp Thickness (PTK), Fruit Decay (FD), Pericarp Weight (PWT), Dry Matter (DM), Moisture Content (MC), Total Soluble Solid (TSS), Shelf Life (SL)

*=P < 0.05,
**=P<0.01
NS = not significant

CHAPTER FIVE

5.0 DISSCUSION

5.1 WEIGHT LOSS

Respiration is a central process in living cells that mediates the release of energy through the breakdown of carbon compounds and this gives an indication of the overall metabolism of the plant part which utilizes the plant product as its substrate thereby leading to weight loss (Kays, 1991).

The significantly ($P < 0.01$) lowest weight loss was recorded by Royal fruits (2.57g), less than fruits of Cal J (3.33g) and Power (3.56g) and this may be due to variations in the genetic make up of the individual cultivars in response to respiration rates which is an indication of weight loss, as indicated by Kays (1991). Previous studies conducted to compare weight loss (water loss) in pepper cultivars showed significant variation in the varieties during storage (Bosland, 1993; Smith *et al.*, 2007). The thickest pericarp recorded in Royal fruits (3.74 mm) over Power and Cal. J might have partly caused the reduction in weight loss of Royal fruits. Maalekuu *et al*. (2003) who emphasised the possibility of thin pericarp tissue, among other factors associated with increased weight loss in sweet pepper fruits.

Fruits harvested from fields amended with NPK plus 'Asasewura' cocoa fertilizer recorded, significantly ($P = 0.01$) the lowest weight loss (2.68g) among fruits from fields amended with NPK plus Sulphate of ammonia (3.44g), Poultry manure (3.36g) and Control (3.07g) fields. This might be due to the relatively high and readily available calcium in 'Asasewura' cocoa fertilizer which is characterised by the ability to increase cell formation and reduce respiration rates. This might have contributed to the reduction of weight loss in fruits harvested from NPK plus ‘Asasewura’ cocoa fertilizer amended fields. Sharma *et al*. (1996) in their observations confirmed calcium’s ability to reduce respiration, which is an indication of weight loss (Kays, 1991).

5.2 FRUIT FIRMNESS

Fruit firmness is a criterion often used to evaluate fruit quality as it is directly related to fruit storage potential. It is also related to the likelihood of bruising when fruits are subjected to impact during handling (Lesage and Destain, 1996).

The difference in fruit firmness observed among cultivars Cal. J (2.99N), Power (2.69N) and Royal (3.42N) might be due to the genetic difference of the individual cultivars. This confirms findings of Bosland (1993), who stated that, genetic background among other factors can affect fruit firmness. Again, difference in weight loss rate recorded by individual cultivar types might have influenced the difference in fruit firmness. Lownds *et al*. (1993) found a pronounced decrease in fruit firmness to be associated with increased weight loss during prolonged storage of pepper.

Relatively low nitrogen levels in NPK plus ‘Asasewura’ cocoa fertilizer amended fields might have depressed calcium uptake for plant utilization to contribute to fruit firmness (3.31N) than fruits harvested from Poultry manure (2.91N) and NPK plus Sulphate of ammonia (2.80N) amended fields where nitrogen level were relatively high. Findings of Siddiqi *et al*. (2002), Akl *et al.* (2003), Heeb *et al.* (2005) who reported that nitrogen dominated supply may markedly increase the incidence of depression of calcium uptake which could lead to decreased firmness in fruits harvested from fields amended with Poultry manure and NPK plus Sulphate of ammonia. Crisosto *et al*. (1995) also reported that excess nitrogen during the pre-harvest stage can reduce fruit firmness.

5.3 GENERAL APPEARANCE

General appearance of fruits plays an important role in making purchasing decisions (Kays, 1999). Colour, cracks, bruises, firmness, etc are factors mostly used to assess general appearance which double as important factors in the consumer preference of tomatoes.

Variations in genetic make up of the individual cultivars might have revealed the differences in general appearance of fruits of Power (3.32), Royal (4.03) and Cal. J (3.38). An earlier research conducted by Maalekuu *et al*., (2004) indicated that, cultivar types in sweet pepper could influence fruit general appearance. Lower weight loss recorded in fruits of Royal than Cal J and Power might have contributed positively to general appearance in Royal fruits (4.03) than fruits of Cal. J (3.38) and Power (3.32). The low weight loss could have probably led to little shrivelling and stabilised fruit firmness during storage. Kays (1999), indicated that, general appearance of fruits is affected mainly by fruit firmness, weight loss and decay incidence.

Relatively high and readily available calcium levels in ‘Asasewura’ cocoa fertilizer might have increased fruit firmness and also lowered biosynthesis in carotenoids which are responsible for tomato fruit colour. This could have improved general appearance of fruits harvested from NPK plus 'Asasewura' cocoa fertilizers fields (3.93) more than fruits harvested from fields amended with NPK plus Sulphate of ammonia (3.44) and Control (3.07). Studies conducted by Kays, (1991), indicated that insufficient calcium supply will decrease the biosynthesis of carotenoids, which are responsible for tomato fruit colour (Dorais *et al*., 2001).

The best general appearance in fruits harvested from Poultry manure amended fields (3.87) than those from Control (3.07) and NPK plus Sulphate of ammonia fields (3.44) could probably be due to adequate calcium and magnesium levels which have the ability to reduce defects such as shoulder cracks, increase fruit firmness and to increase overall fruit quality respectively. Hao and Papadopoulos, (2004) reported that, under conditions of severe magnesium deficiency the size and overall appearance of the fruit may be reduced, unless accompanied by a commensurate increase in calcium supply.

5.4 MEMBRANE ION LEAKAGE (%EC)

Besides wilting and dehydration of horticultural products during storage, deterioration of plant tissues is also of great concern to food and horticultural scientists. Evidence gathered supports membrane damage as the key event leading to a cascade of biochemical reactions culminating in tissues deterioration (Maalekuu *et al*., 2005).

The lowest membrane ion leakage recorded by Royal fruits (12.30%) as compared to fruits of Cal.J (13.91%) and Power (15.49%) may be partly due to the genetic make up of the cultivars. Pronounced rate of weight (water) loss in Cal. J and Power over Royal might have partly caused the differences in membrane ion leakage. Maalekuu *et al*.

(2005), stated that, membrane ion leakage which is an indicator of loss of membrane integrity was found to increase in pepper genotypes susceptible to high rates of water loss but low in genotypes less susceptible to water loss during storage.

Probably, the readily available calcium levels in NPK plus ‘Asasewura’, cocoa fertilize amended fields might have caused relatively low loss of membrane integrity resulting from membrane damage. This could have caused the lowest weight (water) loss rate which might have also led to low membrane ion leakage of fruits harvested from fields amended with NPK plus ‘Asasewura’, cocoa fertilizer (12.52%) than those from fields amended with Poultry manure (14.61%), NPK plus Sulphate ammonia (13.87%) and Control (14.61%) respectively. Boros-Matovina and Blakes (2001) reported that, membrane ion leakage is a measure of loss of membrane integrity resulting from membrane damage which leads to water loss and loss of other membrane-bound solute.

5. 5 PERICARP THICKNESS

Pericarp thickness is an important tomato quality attribute which is highly associated with many quality characteristics such as fruit firmness, fruit defect, and weight loss. The inherent characteristics of cultivars might have caused the differences in fruit pericarp thickness among the fruits of Royal (3.74 mm), Power (3.05 mm) and Cal. J (2.83 mm) (Table 11). It is possible that, thickest pericarp recorded for Royal (3.74mm) reduced weight loss and softness in Royal fruits than Power and Cal. J. Maalekuu *et al*. (2003) emphasised the possibility of thin pericarp tissue and low epicuticular wax content led to increase weight loss in sweet pepper fruits.

The additional plant nutrients likely to be available at fields amended with fertilizers might have increased the pericarp thickness in fruits harvested from those fields than fruits harvested from Control (no amendment). Slower but continuous release of plant nutrients characterised by poultry manure might have continuously increased protein and starch content of the fruits harvested from Poultry manure amended fields to increase fruit pericarp thickness (3.65 mm) than fruits harvested from Control fields (2.85 mm), NPK plus 'Asasewura', cocoa fertilizer (3.36 mm) and NPK plus Sulphate of ammonia (3.09 mm) amendment fields (Table 11). These results are in contrast with the findings of MacRae *et al*. (1993), which indicated lower yields in the transition from conventional to organic production due to slower nitrogen release from organic materials compared to synthetic fertilizers. Relatively higher pericarp thickness of fruits harvested from fields amended with NPK plus 'Asasewura' cocoa fertilizer (3.36mm) over fruits harvested from fields amended with NPK plus Sulphate of ammonia amended fields (3.09 mm) could be due to the relatively greater calcium levels in NPK plus 'Asasewura' cocoa fertilizer which might have increased cell formation of the fruits hence increased fruit thickness.

The greater pericarp thickness recorded for the interaction of Cal J, Royal and Poultry manure (3.00 mm and 4.26 mm respectively), NPK plus 'Asasewura' cocoa fertilizer (2.99 and 3.77mm) and NPK plus Sulphate of ammonia (2.96 mm and 3.67mm) over Control (2.37 mm and 3.27 mm) respectively (Table 11) may be due to the availability of additional nutrients supplemented by the individual fertilizers which may have aided cell, protein and starch build-up, to increase pericarp thickness than fruits harvested from control fields.

Power grown in Poultry manure amended fields (3.68 mm) produced the thicker pericarp than Power grown in soil amended with ‘Asasewura’, cocoa fertilizer (3.32 mm), Control (2.57 mm) and in soil amended with Sulphate of ammonia (3.67 mm) (Table 11). This may be due to the slower but continuous release of plant nutrients (particularly Nitrogen) for plant utilization in Poultry manure which could increase protein and starch content of the fruits, than inorganic fertilizer treated fields.

Continues but slow release of nitrogen by poultry manure might have caused more cell build-up to increase pericarp thickness in Royal fruits in Poultry manure interaction (4.26 mm) than the pericarp thickness of the interaction of Royal fruit in NPK plus ‘Asasewura’ cocoa fertilizer (3.77 mm) and Royal fruits in NPK plus Sulphate of ammonia (3.67 mm). The differences observed under the interactions of the individual cultivars and soil amendment types might be due to the inherent ability of the individual cultivars to utilize the readily available nutrients released by the different soil amendment types.

5.6 FRUITS DECAY

Among the principal causes of postharvest losses is decay (Steven and Celso, 2005).

The significant differences observed among the fruits of Royal (6.0%), Power (11.7%) and Cal. J (8.7%) in decay incidence may be due to the differences in the genetic make up of the individual cultivar types which might have varied the ability to resist decay pathogens among the cultivars. An earlier work by Maalekuu *et al*. (2004) on pepper revealed that, cultivar types could influence fruit decay.

Comparatively higher nitrogen levels during the pre harvest period as characterised by poultry manure might have increased the susceptibility to decay of fruits harvested from Poultry manure (9.20) field than fruits from fields amended with NPK plus‘ Asasewura’ cocoa fertilizers (6.80). Bachmann and Earles (2000) indicated the possibility of produce stressed by high rate of nitrogen to be susceptible to postharvest decay (diseases) in fruits.

Again, the relatively high nitrogen levels in Poultry manure amended fields might have interfered with calcium (a cell forming nutrient) availability to the plant, hence leading to weak cell formation and easy degradation of cells in fruits which could increase decay incidence of fruits more than those harvested from fields amended with NPK plus ‘Asasewura’ cocoa fertilizers, where nitrogen levels were moderately low. Studies conducted by Siddiqi *et al*., (2002), Akl *et al.*(2003) and Heeb *et al.*(2005b) associated increase in fruit decay (rot) with high nitrogen levels dominated nutrients, an effect which is attributed to a depression of calcium uptake.

Attack by most organisms that cause deterioration in fruits follows physical injury or physiological breakdown. The relatively high decay recorded in fruits harvested from Control (10.4%) fields than those harvested from fields amended with NPK plus ‘Asasewura’ cocoa fertilizer may be due to additional calcium levels in ‘Asasewura’ cocoa fertilizer which reduced the incidence of shoulder cracks and other physiological disorders that lead to deterioration of fruits. Lichter *et al*. (2002) reported the ability of calcium to reduce the incidence of shoulder check crack, and other physiological disorder that leads to deterioration in fruit quality.

5.7 PERICARP WEIGHT

Pericarp (fruit) weight and composition depend on the balance between inward and outward fluxes to and from fruit (mostly water and carbon), which involve many different processes.

The significantly higher pericarp weight recorded by fruits harvested from Power (3.76g) and Royal (3.67g) than Cal. J fruits (3.08g) may be due to the genetic ability of the individual cultivars to absorb more water and or build up more carbon compounds which has direct relationship to pericarp (fruit) weight. There is the probability that, lower weight (water) loss recorded in Royal fruits could have accounted for the increase in pericarp weight of Royal fruits (3.67g) than Cal. J fruits (3.08g). Wu *et al*. (2003) reported that, transpiration in nectarine fruits lead to water loss and may decrease the fruit weight. Power fruits which recorded the heaviest pericarp weight (3.76g) and the highest weight (water) loss (3.57g) is an indication that, apart from water loss, the break down of carbon compounds as reported by Kays, (1991) could reduce fruit pericarp weight. Hence there is a probability that Power fruits had lower rate of carbon compounds break down than Cal J. fruits.

Comparatively heavy pericarp weight in fruits harvested from fields amended with Poultry manure (4.13g) than fruits harvested from fields amended with NPK plus

‘Asasewura’ cocoa fertilizer (3.47g), NPK plus Sulphate of ammonia (3.59g) and Control (2.83g) field may be due to the continuously but slower release of plant nutrients such as nitrogen which could increase protein and starch content of fruits harvested from fields amended with Poultry manure which might have increased fruit weight than fruits harvested from other fields. Faria *et al*. (2003) reported that cattle manure (inorganic fertilizer) significantly increased yield and mean fruit weight of melon.

The significantly higher pericarp weight of fruits harvested from fields amended with NPK plus ‘Asasewura’ cocoa fertilizer (3.47g), NPK plus Sulphate of ammonia (3.59g) than Control (2.83g) may partly be as a result of moderately high calcium in ‘Asasewura’ cocoa fertilizer which is characterized to reduce respiration rate which is phenomenon of weight (water) loss (Kays 1991). Again the presence of relatively high and readily available nitrogen in NPK plus Sulphate of ammonia might have increased protein and starch content of fruits and hence increased fruits weight than fruits from the Control fields.

5.8 DRY MATTER

High dry matter or low water content of the tomato has been reported to affect fruit taste positively because the major components of tomato taste; sugars and acids, are more concentrated (Auerswald *et al*., 1999), which fits well with consumers’ demand for high quality produce (El-Saeid *et al*., 1996). The highest dry matter content of Royal fruits (0.35g) compared to fruits of Power (0.28g) and Cal J (0.27g) (Table 16) could be due to the genetic make up of the individual cultivars. Differences in fruit dry matter based on cultivar dependence has been indicated by Hibler and Hardy (1999), in peel and pulp of cooking banana and plantain. It is possible the lowest weight loss, which probably might have been influenced by low respiration (a process by which stored organic materials are broken down into simple end products with a release of energy) rate, contributed to the more dry matter in fruits of Royal than fruits from Power and Cal J. Opara and Tadesse, (2000) reported that respiration results in loss of fruit dry matter and weight in pacific rosie apples fruit.

The relatively high dry matter in fruits harvested from fields amended with various fertilizers NPK plus Sulphate of ammonia (0.32g), Poultry manure (0.29g) and NPK plus 'Asasewura' cocoa fertilizer (0.33g) than fruits harvested from control (0.25g) fields may be mainly due to the additional plant nutrients for plant utilization supplied by the fertilizers used to amend fields which could improve cell formation to increase fruits dry matter.

5.9 MOISTURE CONTENT

Fruits and vegetables contain large quantities of water in proportion to their weight. Norman, (1992) indicated that, tomato fruits contain about 93 percent moisture. Genetic variation might have caused highly significant variation among fruits moisture content of Power (92.51%), Cal J (91.12%) and Royal (90.42%) (Table18). The highest moisture content recoded by fruits from Power than Cal J and Royal might have been influence by the genetic make up of the individual cultivars.

The significantly higher moisture content recorded from fruits harvested from fields amended with Poultry manure (92.93%) than those harvested from fields amended with

NPK plus 'Asasewura' cocoa fertilizer (90.46%), NPK plus Sulphate of ammonia (91.05%) and Control (no amendment) fields (90.96%) respectively may be due to the ability of Poultry manure (organic fertilizer) to retain more moisture (water) for plants utilization over relatively long period than fields amended with inorganic fertilizers and control. Studies by Barrett *et al.* (2007) found results that indicated significant differences in moisture content between tomatoes produced under inorganic and organic production systems.

5.10 TOTAL SOLUBLE SOLID (TSS)

Total soluble solids are known to increase fruit quality (Loboda and Chuprikova, 1999), which fits well with consumers' demand for high quality produce (El-Saeid *et al*., 1996). Significant differences in total soluble solids observed between fruits of Power (3.73% Brix), Cal. J (3.65% Brix) and Royal fruits (4.17 % Brix) (Table 20) may be partly due to comparatively high dry matter content recorded by fruits of Royal (0.35g) than dry matter content in fruits of Power (0.28g) and Cal J (0.27g) (Table 16). Hao, *et al.* (2000) reported that tomato that, fruits with high dry matter content usually have higher total soluble solids, and thus have better taste and flavour.

The higher total soluble solids recorded for fruits harvested from the fields amended with NPK plus 'Asasewura' cocoa fertilizer (4.04%) as compared to fruits from Control (3.42%) and NPK plus Sulphate of ammonia (3.91%) amended fields (Table 21) may partly be due to their higher dry matter content (Table 17). Increased total soluble solid of fruits harvested from fields amended with Poultry manure (4.02%) over fruits harvested from Control (3.42%) and NPK plus Sulphate of ammonia (3.91%) amended fields may be as a result of probably higher biosynthesis or degradation of polysaccharides during storage in fruits harvested from fields amended with Poultry manure. Artes *et al*. (1999) associated increment of total soluble solids in tomato with degradation of polysaccharides.

The higher total soluble solid at the interaction of cultivar Cal J and NPK plus Sulphate of ammonia than the interaction of Cal J and Control as well as the higher total soluble solids in interactions among Royal and Power fruits and NPK plus Sulphate of ammonia, Poultry manure and NPK plus 'Asasewura' cocoa fertilizer respectively than the interaction of Royal, Power fruits and Control fields respectively might have been done to the relatively high fruits dry matter content recorded from fertilizer amended fields than those from Control fields. Hao *et al*., (2000), associated high total soluble solids with higher dry matter content.

5.11 SHELF-LIFE

Fruits shelf life during storage is an important feature from a producer's and a distributor's point of view, allowing the determination of risks arising from the loss of commercial value of fresh fruit in trade turnover (Radajewska and Borowiak, 2002).

Variations observed in fruit shelf life among cultivars Royal (10.29 days), Cal. J (7.93 days) and Power (6.68 days) (Table 23) may probably be due to genetic makeup of the individual cultivars' ability to minimised respiration rate, weight (water) loss and other factors which affect fruits shelf life negatively. It is possible that, the variation in fruits firmness among the Royal (3.42 N), Cal J (2.99 N) and Power (2.99 N) contributed to similar variation pattern in fruit shelf life among the Royal, Cal .J and Power (Table 24).

Significantly, NPK plus ‘Asasewura’ cocoa fertilizer amended fields produced fruits that could store longer duration (9.39 days) compared to those Control (7.92days), Poultry manure (8.32 days) and NPK plus Sulphate of ammonia (7.58 days) amended fields. The ability of NPK plus ‘Asasewura’ cocoa fertilizer amended fields fruits to the longest shelf life may be due to relatively, high and readily available calcium levels (which has the ability to extend fruit shelf life). Sharma *et al.*, (1996) reported the ability of calcium nutrients to extend shelf life of fruits. Also other desirable characteristics of calcium such as its ability to delay ripening and senescence, reduce respiration, increase firmness and reduce physiological disorders as reported by Sharma *et al.* (1996) could probably have affected the shelf life of tomato fruits stored possibly.

5.12 CORRELATION OF TOMATO FRUITS QUALITY TRAITS

Results obtained from correlation analysis are of great importance in determining the relationship between postharvest qualities of tomato (*Lycopersicun esculentum* Mill.) fruits during storage. Fruit weight loss had a high and negative significant correlation with fruit firmness (-0.71), membrane ion leakage (0.63), general appearance (-0.44) and shelf life (-0.70) respectively could be an indication that, increase in weight loss in fruits is directly proportional to decrease in fruit firmness. Weight (water) loss is the principal cause of fruit softening (Wilson *et al*., 1999). Increase in fruit weight loss could have a direct relationship with increase membrane ion leakage. Membrane ion leakage which is an indicator of loss of membrane integrity was found to increase in pepper genotypes susceptible to high rates of water loss (Maalekuu *et al*., 2005).

Fruit general appearance is negatively affected by weight (water) loss since increase in fruit water loss reduces fruit firmness, increases shriveling which are important criteria for assessing fruit general appearance qualities. Wilson *et al*., (1999) reported that, weight (water) loss is the principal cause of fruit softening and shriveling which are among factors mostly used to assess fruits general appearance.

Fruit general appearance showed high significant correlation with fruit pericarp thickness (0.69). This implies that, increase in pericarp thickness could reduce weight loss, fruit softening and shriveling which increases fruit general appearance.

Fruit firmness had high significant correlation with fruit shelf life (0.73) and fruit decay (-0.60). Increased in fruit firmness may be directly proportional to increased in fruit shelf life. It may be possible that, increased in fruit firmness could have decreased the susceptibility of the fruits to decay pathogen infestation which might lead to decrease decay incidence in fruit.

The significant but negative correlation between membrane ion leakage with fruit decay (-0.61) and shelf life (-0.67), suggest that increased in fruit membrane ion leakage could be directly proportional to decrease in fruit decay and shelf life. Loss of membrane integrity resulting from membrane damage leads to water loss and loss of other membrane-bound solutes (Boros-Matovina and Blakes, 2001), an indicator for predicting fruit shelf life and decay.

Fruit pericarp thickness indicated positive correlation with pericarp weight (0.68), dry matter (0.65), shelf life (0.63) and total soluble solids (0.73) (Table 25). The increase in fruit pericarp thickness probably resulted in increased fruit pericarp weight, dry matter, total soluble solids, and shelf life. Fruit dry matter content showed high negative correlation with fruit moisture content (-0.80), which means that, increased dry matter could result in decreased fruits moisture content.

CHAPTER SIX

6.0 CONCLUSION

The study revealed that, pre harvest (soil amendment and cultivar types) practices can influence post harvest performance of tomato (*Lycopersicon esculentum* Mill.) fruits.

Fruits of Royal and Power on average, ranked best and least respectively among the cultivar types in postharvest quality performance.

Fruits harvested from fields amended with NPK plus 'Asasewura' cocoa fertilizer performed best among the soil amendments on post harvest quality of tomato studied. However, fruits harvested from all fertilizer (NPK plus 'Asasewura' cocoa fertilizer, NPK plus Sulphate of ammonia and Poultry manure) amended fields on average performed better than fruits harvested from Control (no amended) fields.

Fruit weight loss had indirect consequence on fruit firmness, general appearance and shelf life but direct effect on increased membrane ion leakage in tomato cultivar studied. Membrane ion leakage influenced fruit decay negatively in tomato cultivar studied. Pericarp thickness of tomato fruits affected pericarp weight, dry matter, shelf life and total soluble solids positively.

Based on the study, both exotic and local types of tomato should be promoted with emphasis on the exotic types such as Royal which performed comparatively better with regard to postharvest quality.

Moreover, tomato farmers are encouraged to amend their fields with NPK plus 'Asasewura' cocoa fertilizer to ensure higher yield and fruit quality.

6.1 RECOMMENDATION

In order to improve postharvest quality of tomato, it is recommended to reduce fruit weight loss, fruit membrane ion leakage, fruit decay and improve fruit firmness, fruit general appearance, fruit shelf life and total soluble solids of fruits through soil amended with 250kg/ha of NPK (15-15-15) and top dress with 250kg/ha of 'Asasewura' cocoa fertilizer.

Moreover, cultivars Royal and Cal. J (exotic) are recommended for cultivation since on average their fruits performed better in postharvest qualities than fruits of Power (local) after 7 days storage at 26.85C and 85.75% RH.

REFERENCES

Adams, P., Davis, J. N. and Winsor, G.W. (1978). Effect of nitrogen, potassium and magnesium on the quality and chemical composition of tomatoes grown in peat. Journal of Horticultural Science 53:115-122.

Adb-Alla, A. M., Adam, S. M., Abou-Hadid, A. F. and Iman, S. S. B. (1996). Temperature and fertilizer effects on tomato productivity. Acta Hort.34**:** 113-119.

Adu-Dapaah, H. K and Oppong-Konadu, E.Y, (2002), Tomato production in four major tomato-growing districts in Ghana: Farming practices and production constraints. Ghana Jnl. Agric. Sci, 35, 11-22.

Akande, M. O and Adediran, J. A. (2004). Effects of terralyt plus fertilizer on growth nutrients uptake and dry matter yield of two vegetable crops. Moor J. of Agric. Res. 5:12-107.

Akl I. A, Savvas, D., Papadantonakis, N., Lydakis-Simantiris, N., Kefalas, P. (2003). Influence of ammonium to total nitrogen supply ratio on growth, yield and fruit quality of tomato grown in a closed hydroponic system. European Journal of Horticultural Science 68, 204-211.

AOAC (1984). Official Methods of Analysis (14th Edn.) Association of Official Analytical Chemists, Washington D.C.

AOAC (1990). Official Methods of Analysis (15th Edn). Association of Official Analytical Chemists, Washington D.C.

Artes, F., Conesa, M. A., Hernandez, S and Gil, M. I. (1999). Keeping quality of fresh-cut tomato. Postharvest Biology and Technology 17: 153-162.

Artherton, J. G. and Rudich, J. (1986). *The Tomato Crop*. Chapman and Hall press pp. 260-273.

Asharf, M. (2004). Some important physiological selection criteria for salt tolerance in plants. Flora Vol,199. Pp. 361-377.

Auerswald, H., Schwarz, D., Kornelson, C., Krumbein, A., Brückner, B. (1999). Sensory analysis, sugar and acid content of tomato at different EC values of the nutrient solution. *Scientia Horticulturae* 82, 227-242.

Bachmann, J. and Earles, R. (2000). Postharvest handling of fruits and vegetables. ATTRA Horticultural Technical Note 2000, pp: 19.

Banaras, M., Lownds, N. K and Bosland, P.W. (1988). Relationship of physical properties to postharvest water loss in pepper fruits (*Capsicum annuum* L.). *Pak. J. Bot.*, 26(2): 321-326.

Bar Tal, A and Pressman, E. (1996). Root restriction and potassium and calcium solutions concentrations affect dry-matter production, calcium uptake and blossom-end rot in greenhouse tomato. Journal of American Society for Horticultural Science 121:649-655.

Barrett, D. M, Weakley, C., Diaz, J. V and Watnik, M, (2007). Qualitative and nutritional differences in processing tomatoes grown under commercial organic and conventional production systems. *J. Food Sci* 72:441–451.

Batu, A. (2003). Determination of acceptable firmness and colour values tomatoes. J. Food Eng., 61: 471-475.

Batu, A. (1998). Some factors affecting on determination and measurement of tomato firmness, Tr. J. of Agriculture and Forestry, 22, 411-418.

Bohner, J and Bangerth, F. (1988). Effects of fruit set sequence and defoliation on cell number, cell size and hormone levels of tomato fruits (*Lycopersicon esculentum* Mill.) within a truss. Journal of Plant Growth Regulation .7:141–155.

Borsos-Matovina, V and Blake, T. J. (**2001).** Seed treatment with the antioxidant Ambiol enhances membrane protection in seedling exposed to drought and low temperature. Trees 15: 163-167.

Bosland, P. W. (**1993).** An effective plant field-cage to increase the production of genetically pure Chile (Capsicum spp.) seed. HortScience 28:1053.

Cheour, F. Willemot, C. Arul, J. Makhlout, J and Desjardins, Y. (1991). Postharvest response of two strawberry cultivars to foliar application of calcium chloride. HortScience 26:1186-1188.

Claussen, W. (2002). Growth, water use efficiency, and proline content of hydroponically grown tomato plants as affected by nitrogen source and nutrient concentration. Plant and Soil 247, 199-209.

Conclin, N. C. and Thompson, G. (1993) Product quality in organic and conventional produce: is there a difference? Agribusiness 9: 295-307.

Crisosto, C. H., Mitchell, F. G and Johnson, S. (1995). Factors in fresh market stone fruit quality. Postharvest News and Information 6:17-21.

Dadzie, B. K. and Orchard, J. E. **(1997).** *Routine Postharvest Screening of Banana or Plaintain Hybrids; Criteria and Method.* International Plant Genetic Resources Institute, IPGRRI, CTA, Wageningen, Netherlands. Pp.13-2011.

Dobrzanski, B and Rybezynski R. (1998). A simple device for accurate strain measurement on apple fruits. Acta Horticulture, 421: 223-230.

Dorais, M., Papadopoulos A. P., Gosselin, A. (2001). Greenhouse tomato fruit quality. *In*: Janick, J. (ed.), *Hort. Rev*., 5: 239–319.

Ellis, W.O., Agbemafle, R., Oldham, J. H. and Nsiah, K. (1998). Tomato paste production in the rural scale level. In Proceedings of a workshop to evaluate outputs and identify further vegetables research priorities in the Brong Ahafo Regions of Ghana.10-11 September, 1998, Sunyani. pp. 56-71.

El-Saeid, H.M., Imam, R.M. and El-Halim, S.M.A. (1996). The effect of different night temperatures on mophorlogical aspect, yield parameters and endogenous hormones of sweet pepper. Egyptian Journal of Horticulture., 23:145-165.

Emmons, C. L. W. and Scott, J. W. (1997). Environmental and physiological effects on cuticle cracking in tomato. Journal of the American Society for Horticultural Science 122: 797-801.

Ewulo, B. S. (2005). Effect of poultry and manure on sandy clay loamy soil. J.Anim Vet.Sci.,4:839-841.

Fallahi E., Conway, W. S., Hickey, K. D., Sams, C. E. (1997). The role of calcium and nitrogen in postharvest quality and disease resistance of apples. HortScience 32,831-835.

FAO (1986). Prevention of post harvest losses in fruits, vegetables and root crops. Corporate Document Repository. FAO Training Series no.17/2, FAO, Rome, Italy. FAO Public Division of UN, Via delle Termed di Caracalla www.fao.org/docrep/T0073E/T00. (Publishers/Website, PP)

FAO (2005). Fertilizer Use by Crop in Ghana, First version, FAO, Rome, pp 11.

FAO (2006). Import Surge Brief - Commodities in Developing Countries: No. 5 Ghana: Rice, Poultry and Tomato Paste, FAO, Rome, pp 2.

FAO, (2007). FAOStat, core production 2005. Available online: http://faostat.fao.org/site/340/default.aspx. 12-04-2010.

Faria, M. B., Costa, N. D. Soares, J. M., Pinto J.M and Lins, J. M. (2003). Effect of organic matter, nitrogen and micronutrients on yield and quality of melon. *Hortic. Bras.*, 21: 55–59.

Flores P, Navarro J. M, Carvajal M, Cerdá A and Martínez V. (2003). Tomato yield and quality as affected by nitrogen source and salinity. *Agronomie* 23, 249-256.

Fraser , P. D. Truesdale , M. R. Bird, C. R. Schuch, W. and Bramley , P.M.(1994). Carotenoid biosynthesis during tomato fruit development. Plant Physiology, v.105, p.405-413.

Hamouz, K., Lachman, J., Dvořak, P and Piviec, V. (2005). The effect of ecological growing on the potaotes yield and quality. Plant Soil Environ. 51 (9): 397 – 402.

Hao, X, and Papadopoulos, A. P. (2004). Effects of calcium and magnesium on plant growth, biomass partitioning, and fruit yield of winter greenhouse tomato. HortScience 39, 512-515

Hao, X., Papadopoulos, A.P and Vollans, K. (2000). Effects of electrical conductivity (EC) and its diurnal changes in nutrient feedings on fruit yield and quality of greenhous tomato grown in rockwool. Greenhouse and Processing Crops Research Centre, Agriculture and Agri-Food Canada, Harrow, ON, Canada, pp. 16-17.

Hartz. T. K., Johnson P. R., Francis, D. M and Miyao, E. M. (2005). Processing tomato yield and fruit quality improved with potassium fertigation. Hort. Science 40, 1862-1867.

Heeb A., Lundegårdh, B., Ericsson, T., Savage, G.P. (2005) Nitrogen form affects yield and taste of tomatoes. Journal of the Science of Food and Agriculture 85, 1405- 1414.

Heuvelink, E. (1997). Effect of fruit load on dry matter partitioning in tomato. *Scientia Horticulturae* 69:51–59.

Hibler, M and Hardy, D. (1999). Breeding a better banana. IDRC Report 22(1), pp. 16-18.

Ho, L. C. (1999). The physiological basis for improving tomato fruit quality. Act Horticulturae, Wageningen, n. 487, p. 33-40, Kalyani Publishers. New Delhi, 110002. p. 223.

Jones, J. (1999). Tomato plant culture: in the field, greenhouse, and home garden. CRC Press. Boca Raton, FL 1-30.

Kabelka, E., Yang, W. and Francis, D. M. (2004). Quality and physiological parameters of tomato (Lycopersicon esculentum Mill.) fruits of Lithuanian selection. J Amer Soc Horticultural Sci. 2004; 129(2): 250-7.

Kader, A. A. (1992). *Postharvest Technology of Horticultural Crops*. Second edition,Univ. Calif., Div. of Agr. and Nat. Resources, Publ. 3311, pp. 296.

Kader, A. A. (1994). Fruit maturity, ripening, and quality relationships. Perishables Handling Newsletter No. 80:2.

Kader, A. A. (2005): Increasing food availability by reducing postharvest Losses of fresh produce. P. 2169-2175 in: Mencarelli, F. and Tonutti, P. (eds.): Proc. 5th Int. Postharvest Symp. Acta Hort. 682, Belgium: ISHS.

Kays, S. J. (1999). Postharvest factors affecting appearance. Postharvest Biology Technology 15: 233-247.

Kays, S. J., (1991), *Postharvest physiology of perishable plant products*. Van Nostrand, pp 532.

Kirk, R. S., and Sawyer, R. (1991). Pearson's Composition and analysis of foods. Longman Science. Tech. Engl, Pp. 223-228.

Knowles, L., Trimble, M.R., Knowles, N. R., (2001). Phosphorus status affects postharvest respiration, membrane permeability and lipid chemistry of European seedless cucumber fruit (*Cucumis sativus* L.). Postharvest Biol. Technol. 21, 179 – 188.

Lesage, P and Destain, M., (1996). Measurement of tomato firmness by using a Non-destructive mechanical sensor. Postharvest Biology and Technology, 8, 45-55.

Lichter, A., Dvir, O., Fallik, E., Cohen, S., Golan, R., Shemer, Z., Sagi, M. (2002). Cracking of cherry tomatoes in solution. Postharvest Biology and Technology 26, 305-312.

Loboda, B. P. and Chuprikova, O. A. (1999). An agroecological evaluation of growing media made from rock containing zeolites with regard to greenhouse cultivation of green peppers. *Agrokhimiya*, 2:67-72.

Lownds, N. K., Banaras, M and Bosland, P. W. (1993) Relationship between postharvest water loss and physical properties of pepper fruit (*Capsicum annum* L.). – Hort. Science, 28: 1182-1184.

Maalekuu, K., Elkind, Y., Tuvia-Alkalai, S., Shalom, Y., Fallik, E. (2003). Quality evaluation of three pepper cultivars after prolonged storage. Advance Horticultural Science 17: 187-191.

Maalekuu, K., Elkind, Y., Tuvia-Alkalia, S. Shalom, Y., Fallik, E. (2004). The influence of the harvest season and cultivar type on several quality traits and quality stability of three commercial sweet peppers during the harvest period. Adv. Hort. Sci., 18 pp.18-25.

Maalekuu, K., Elkind, Y., Tuvia-Alkalai, S., Shalom, Y., Fallik, E. (2005). Characterization of physiological and biochemical factors associated with postharvest water loss in ripe pepper fruits during storage. Journal of American Society for Hort. Science 130 (5), pp. 735-741.

Marschner, H. (1995). *Mineral Nutrition of Higher Plants*. Academic press, London, 4th printing, pp: 889.

Mengel, K. and Kirkby, E.A.(2001). Principles of Plant Nutrition. 5th ed., Kluwer Academic Publishers, Dordrecht.

McCollum, T. G., Chellemi, D. O., Rosskopf, E. N., Church, G. T. and Plotto, A. (2004). Postharvest quality of tomatoes produced in organic and conventional production systems. American Society of Horticulture Science Meeting. Horticulture Science. 40(4):959.

Mitchell, F. G., Mayer, G., Biasi, W. (1991). Effect of harvest maturity on storage performance of Hayward Kiwifruit. Acta Hort. 297: 617-628.

Mondal, M. F. (2000). Production and Storage of Fruits (in Bangla). Published by Afia Mondal. BAU Campus, Mymensingh-2202. Pp-312.

Morgan, L and Lennard, S. (2000). Hydroponic Capsium Production. A Comprehensive Practical and Scientific Guide to Commercial Hydroponic Capsicum production, Casper Publications Pty Ltd. Narabeen, Australia. Pp 403-409

Niklis, N. D., Siomos, A. S. and Stake Takis, E. M. (2002). Ascorbic acid, soluble solids and dry matter content in sweet pepper fruit: change during ripening. Journal of Vegetable Crop Production. 8: 41-51.

Norman, J. C. (1992). Tropical Vegetable Production. Macmillan press pp 52-67.

O'brien, M. Cargill, B. F. and Fridley, R. B. (1983). Principles and Practices for Handling Fruits and Nuts. The AVI Publishing Co., Inc. West Port, Connecticut. Pp. 42.

Oke, M., Ahn, T., Schofield, A. and Paliyath, G. (2005). Effects of phosphorus fertilizer supplementation on processing quality and functional food ingredients in tomato. Journal of Agricultural and Food Chemistry 53, 1531-1538.

Opara, L. U. and Tadesse, T. (2000). Fruit growth characteristics and chronological development of calyx and splitting in pacific rosie apples fruit. Var J. Publications. Pp. 19-25.

Pandey, S. N. and Sinha, B. K. (2006), Plant physiology (Edn 4) Vakas Publishing House PVT LTD. Sharma, India, New Delhi. Pp 88.

Parisi , M., Giordano, I., Pantangelo, A., D'Onofrio, B and Villari G (2006). Effects of different levels of nitrogen fertilization on yield and fruit quality in processing tomato. Acta Horticulturae 700, 129-132.

Peralta, I. E., Spooner, D. M. (2007). History, Origin and Early Cultivation of Tomato (Solanaceae). In: Razdan, M. K. And Mattoo, A. K. Editors. Genetic Improvement of Solanaceous Crops, Vol. 2. Enfi eld, USA: Science Publishers. P. 1-27.

Perez, K., Mercado, J., Soto-Valdez, H. (2003). Effect of storage temperature on the shelf life of Hass avocado (*Persea americana*). Food Sci. Tech. Int., 10(2): 73-77.

Radajewska, B. and Borowiak, I. D. (2002). Refractometric and sensory evaluation of strawberry fruits and their shelf life during storage. Acta Hortic., 567:759-762.

Raupp, J. (1996). Quality of plant products grown with manure fertilisation. Pp 44-48. In comparison of food quality organically versus conventionally grown vegetables, 4th Meeting (AIR3-CT94-1940). www.eap.mcgill.ca/publications/EAP 38.htm.

Saltiveit, M. E. (2002). Respiratory metabolism in The Commercial storage of fruits vegetables, and Department of Agriculture, Handbook 66, available at http://www.ba ars.usda.gov/hb66/index.html. 4-04-2010.

Sergeant, S.A., Maul, F., Sims, C.A. (1998). Implementing the Florida premium – quality tomato program – Florida Tomato Institute University of Florida/Citrus and Vegetables. Magazine. Pp.49-54.

Sargent, S. and Moretti, C. (2002). Tomato. In: Gross, K. Wang, C. and Saltveit, M. (eds.).The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks. United States Department of Agriculture Handbook 66.

http://www.ba.ars.usda.gov/hb66/contents.html. May, 2009.

Seske, L. (1995). Fruit cracking in sweet cherries (Prunus-Avium L.): Some physiological aspects – a mini review. *Scientia Horticulturae* 63:135-141.

Sharma, R. M., Yamdagni, R., Gaur, H. and Shukla, R. K. (1996). Role of calcium in horticulture - A review. Haryana Journal of Horticulture Science. 25(4):205.

Siddiqi, M. Y., Malhotra, B., Min, X. and Glass, A. D. M. (2002). Effects of ammonium and inorganic carbon enrichment on growth and yield of a hydroponic tomato crop. Journal of Plant Nutrition and Soil Science 165, 191-197.

Smith, D., Stommel, J. R., and Raymond, W. M. (2007). Food Composition and Analysis. Postharvest Biology and Technology. Volume 42, Issue 3. Pp 243-247.

Steven, A. S. and Celso, L. M. (2005). Tomato, strawberry fruits and their shelf life during storage. Acta Hortic., 567:759-762.

Sunassee, S. (2001). Use of Litter for Vegetable Production. AMAS 2001. Food and Agricultural Research Council, Reduit, Mauritius, pp. 259 –263.

Von Uexkull, H. R. (1979). Tomato nutrition and fertilizer requirements in the tropics. First International Symposium on Tropical Tomato. P. 65-78.

Voogt, W. and Sonneveld. C. (1997). Nutrient management in closed growing systems for greenhouse production. In: Goto, E. (Ed.). Proc.Intl. Symp. On plant production in closed ecosyterms. Aug.26-29, 1996. Narita, Japan Kluwer Academic Publishers, Dordercht, The Netherlands. Pp 83-102.

Walsh, K. B., Golic, M. and Greensill, C. V. (2004). Sorting of fruit and vegetables using near infrared spectroscopy: application to soluble solids and dry matter content. Journal of Near Infrared Spectroscopy 12:141-148.

Watkins, C. B and Pritts, M. P. (2001). The influence of cultivars on postharvest performance of fruits and vegetables. Proceedings of the Fourth International Conference on Postharvest Science. Acta Hortic.1(553): 59-63.

Wiedemann, P and Neihuis, C. (1998). Biomechanics of isolated plant cuticles. *Botanica Acta* 111:28 – 34.

Williams, L. and Kafkafi, U. (1998). Intake and translocation of potassium and phosphate by tomatoes by late spray of KH2PO4 (MKP). In: Proceedings of the Symposium on Foliar Fertilization: A Technique to Improve Production and Decrease Pollution, Cairo, Egypt, 10-14 December 1995. NRC, pp. 85-90.

Wills, R. B., McGlasson, W. B., Graham, D. and Lee, T. H. (1989). Postharvest: An Introduction to the Physiology and Handling of Fruit, Vegetables and Ornamentals. Van Nostrand Reinhold, New York. Pp. 17-38.

Willumsen, J., Petersen, K. K. and Kaack, K. (1996). Yield and blossom-end rot of tomato as affected by salinity and cation activity ratios in the root zone. HortScience, 71(1):81-98.

Wilson, L. G., Boyette, M. D. and Estes, E. A. (1999). Postharvest handing and cooling of fresh fruits, vegetables and cut flowers for small farms. North Carolina State University Horticulture information leaflets Available at http://www.ces.ncsu.edu/depts/hort/hil/hil-800.html (verified 3 March 2010).

Wu, B. H., Génard, M., Kervella, J., Li, S. H., Laurent, R. (2003). Relationship between skin speckle, soluble solids content and transpiration rate in nectarines. European Journal of Horticultural Science 68:83–85.

Zelená, E., Holasová, M., Zelený, F., Fiedlerová, V., Novotná, P., Landfeld, A. and Houška, M. (2009). Effect of Sulphur Fertilization on Lycopene Content and Colour of Tomato Fruits. Czech J. Food Sci. 27, 80- 84

APPENDICES

1.0 TABLES OF ANALYSIS OF VARIANCE

Table 1.1 Weight Loss

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	2	6.4843	3.2422	24.73	<.001
Fertilizer	3	2.7163	0.9054	6.91	0.002
Cultivar x Fertilizer	6	0.2840	0.0473	0.36	0.896
Residual	22	2.8846	0.1311		
Total	35	12.9398			

Grand mean = 3.15

Table 1.2 Fruit Firmness

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	2	3.18500	1.59250	31.85	<.001
Fertilizer	3	1.37333	0.45778	9.16	<.001
Cultivar x Fertilizer	6	0.15500	0.02583	0.52	0.789
Residual	22	1.10000	0.05000		
Total	35	5.90000			

Grand mean = 3.00

Table 1.3 General Appearance

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	2	3.7622	1.8811	9.83	<.001
Fertilizer	3	4.4000	1.4667	7.66	0.001
Cultivar x Fertilizer	6	1.6867	0.2811	1.47	0.235
Residual	22	4.2111	0.1914		
Total	35	14.3022			

Grand mean = 3.58

Table1.4 Membrane Ion Leakage

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	2	61.247	30.623	26.91	<.001
Fertilizer	3	26.148	8.716	7.66	0.001
Cultivar x Fertilizer	6	2.290	0.382	0.34	0.911
Residual	22	25.032	1.138		
Total35		125.323			

Grand mean = 13.90

Table 1.5 Pericarp Thickness

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	2	5.43814	2.71907	60.58	<.001
Fertilizer	3	4.05387	1.35129	30.11	<.001
Cultivar x Fertilizer	6	0.87734	0.14622	3.26	0.019
Residual	22	0.98744	0.04488		
Total	35	11.88767			

Grand mean = 3.21

Table 1.6 Fruit Decay

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	2	195.120	97.560	16.11	<.001
Fertilizer	3	60.480	20.160	3.33	0.038
Cultivar x Fertilizer	6	15.120	2.520	0.42	0.860
Residual	22	133.200	6.055		
Total	35	452.160			

Grand mean = 8.80

Table 1.7 Fruit Pericarp Weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	2	3.30872	1.65436	17.16	<.001
Fertilizer	3	7.75988	2.58663	26.83	<.001
Cultivar x Fertilizer	6	0.09963	0.01660	0.17	0.982
Residual	22	2.12123	0.09642		
Total	35	13.32501			

Grand mean = 3.51

Table 1.8 Fruit Dry Matter

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	2	0.045680	0.022840	15.44	<.001
Fertilizer	3	0.031488	0.010496	7.10	0.002
Cultivar x Fertilizer	6	0.002996	0.000499	0.34	0.910
Residual	22	0.032540	0.001479		
Total	35	0.116344			

Grand mean = 0.30

Table1.9 Moisture Content

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	2	27.356	13.678	10.76	<.001
Fertilizer	3	31.928	10.643	8.37	<.001
Cultivar x Fertilizer	6	2.140	0.357	0.28	0.940
Residual	22	27.966	1.271		
Total	35	92.044			

Grand mean = 91.35

Table 1.10 Fruit Total Soluble Solids

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	2	1.85701	0.92851	27.90	<.001
Fertilizer	3	2.30490	0.76830	23.09	<.001
Cultivar x Fertilizer	6	0.67970	0.11328	3.40	0.016
Residual	22	0.73206	0.03328		
Total	35	5.65900			

Grand mean = 3.85

Table. 1.11 Shelf Life

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	2	80.5772	40.2886	46.04	<.001
Fertilizer	3	16.6542	5.5514	6.34	0.003
Cultivar x Fertilizer	6	7.4450	1.2408	1.42	0.252
Residual	22	19.2511	0.8751		
Total	35	125.4897			

Grand mean = 8.30

2.0 SOIL ANALYSIS

2.1 Soil Analysis before Experiment

Sample	Organic Carbon %	Organic Matter %	Total Nitrogen %	Exchangeable Cation cmol/kg			Available Phosphors	pH
				Calcium	Magnesium	Potassium		
0-15	1.06	1.82	0.14	6.80	1.20	0.52	211.01	6.28
15-30	0.80	1.38	0.10	5.00	1.90	0.23	122.12	5.83

2.2 Soil Analysis after Experiment

Sample	Organic Carbon%	Organic Matter%	Total Nitrogen%	Exchangeable Cation cmol/kg			Available Phosphorus	pH
				Calcium	Magnesium	Potassium		
NPK+ AS	1.14	1.93	0.14	6.31	1.98	0.56	76.07	7.23
NPK+ SA	1.17	1.89	0.19	3.89	1.70	0.51	75.67	6.55
PM	1.26	2.34	0.25	6.42	2.14	0.55	83.11	6.78
CONT	1.12	1.94	0.13	3.00	3.00	0.48	82.09	6.62

NPK+ Asasewura cocoa fertilizer = (NPK+AS), NPK+ Sulphate of ammonia = (NPK+SA), Poultry manure = (PM), Control = (CONT)

3.0 Poultry Manure Analysis

NITROGEN (%)	PHOSPHORUS (%)	POTASSIUM (%)	CALCIUM (%)	MAGNESIUM (%)	pH
2.852	2.275	24.00	15.60	2.50	7.29
2.567	2.154	25.60	14.00	2.10	7.30