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THE EFFECT OF CALCIUM AND MAGNESIUM ON GROWTH, YIELD AND POSTHARVEST QUALITY OF TWO POPULAR TOMATO VARIETIES

BY

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A THESIS SUBMITTED TO THE SCHOOL OF RESEARCH AND GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF PHILOSOPHY DEGREE IN POSTHARVEST TECHNOLOGY

NYANSAPƆ WↃSANE NO BADWENMA

BY

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DECLARATION

I, Musah Mohammed, hereby declare that this thesis for the degree of MPhil. Postharvest Physiology at Kwame Nkrumah University of Science and Technology is my own work and has never been submitted by myself or any other person at this or any other University. This reported research work is the result of my sole investigations except where duly acknowledged.

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DEDICATION

I fully dedicate this thesis to Allah, Lord of the worlds whom we worship and with whom we ask for help, my beloved late father; Alhaji Musah Alhassan, my beloved mother: Princess Mariama Zakaria. My entire family as well as my friends who have contributed in any form however little to my life.

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ABSTRACT

This study was carried out to investigate the effects of different rates of soil application of Calcium and Magnesium on growth, yield and postharvest quality of Pectomech and Tropimech tomatoes.The experiment was conducted at Central Agricultural Research Station in the field, Kwadaso.The experimental design was a randomized complete block design (RCBD) with four replications. Bulk soil samples were taken at a depth of 0-20cm and then 20-40cm before treatment application for soil analysis. Lime and $MgSO_4$ were broadcast and hoed–in two weeks before transplanting. N: P: K was applied as well as sulphate of ammonia which was the last fertilizer to be applied before harvest. The levels of lime application in this study were 0 tons (the control) and 1.5 tons per hectare. For Magnesium sulphate, the levels applied were 0kg/ha (the control), 30kg/ha and 60kg/ha. From the study, it was observed that effect of magnesium (30kg/ha) and calcium (1.5t/ha) on Pectomech and Tropimech varieties resulted in retention of plant population (50.116, 53.94); leaf area (17.49, 16.21); TSS (4.81, 4.48); Pericarp thickness (5.67, 5.65) and fruit diameter (40.83, 40.60) respectively for the parameters. Effect of Calcium (1.5t/ha) on Tropimech also resulted in decreased number of dropped flowers (70.29), fruit rot (9.52) and shrivelled fruit (2.62). Again, increasing levels of magnesium and Calcium resulted in increased rates of absorption for Calcium (0.96) in Tropimech and Magnesium (0.72) for Pectomech. Generally, both Pectomech and Tropimech responded well to the increasing levels of Magnesium and Calcium and can be adopted to enhance production of Pectomech and Tropimech varieties as well as improve their postharvest quality.

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CHAPTER 1

1.0 INTRODUCTION

The tomato fruit is one of the most widely grown fruit for consumption with over 122 million tons being produced worldwide in 2005 (FAOSTAT, 2005). It plays an important role in human nutrition due to its content in flavonoids, carotenoids and vitamins (Abushita *et al.*, 2000; Scalbert and Williamson, 2000; Rodriquez-Amaya, 1999). B-carotene found in tomatoes is the most potent dietary precursor of vitamin A, the deficiency of which leads to blindness and premature death. Caratenoids and flavonoids when taken regularly and in considerable quantities can provides health benefits by decreasing the risk of disorders (Example certain cancers and cardiovascular diseases) and the incidence of age-related degeneration (Santagelo *et al.*, 2007; Giovannussi, 1999; Weishburger, 1998; Seddon *et al.*, 1994).

Tomato, *Lycopersicon esculentum* Mill is the leading fruit vegetable in Ghana in terms of production and consumption (Blay, 1997). The tomato is widely used in several food preparations in Ghana because of its rich source of vitamin A and C.Tomato from the *Solanaceae* family is a source of vegetable including the egg plant, pepper and among others. Tomato crop is grown both for fresh market and for processing. The fruit may be eaten raw or cooked. Major production areas are Northern Region, Upper East Region, Volta Region, Greater Accra, Ashanti Region and Mankessim/AgonaSwedru/Nsawam areas in Ghana (Norman, 1992). Some of the tomato varieties grown in Ghana include; Navrango, Owusobio, Wosowoso, Fedeabegye and rusta. Recently however, varieties like tropimech, tomato mongal and others are also grown.

In recent years production and fresh marketing of tomato has reduced slowly due to certain factors.

It is also asserted that tomatoes produced in Ghana contain more water compared to those from Burkina Faso and therefore has a shorter shelf-life. Consequently, Ghanaian traders prefer tomatoes from Burkina Faso, the long distance notwithstanding. The economic implication is that tomato producers in Ghana experience a lot of losses in terms of price and marketability of the produce. To reverse this trend, both pre harvest and postharvest factors must be explored. A major pre harvest factor is fertilization.

Application of magnesium and calcium to fruits has the tendency to increase the pulp content, increase the peel thickness and reduce the water content of the fruits. Against this background therefore it is hypothesized that the quality of tomato fruits could be improved with the application of appropriate quantities of magnesium and calcium. Presently, in Ghana, no such work has been done to improve the existing varieties of tomatoes.

1.1Objectives

The objective of the study was to determine:

1. The effect of calcium and magnesium application on the growth and yield of two varieties of tomato.
2. The effect of calcium and magnesium application on the postharvest quality of the tomato varieties.

CHAPTER 2

LITERATURE REVIEW

2.0 Origin

The cultivated tomato is a member of the family *Solanaceae* also known as the "night shade" family and believed to have originated from the Andes region of South America which covers Peru, Ecuador, Colombia and Chile. Although it is generally agreed among taxonomists and breeders alike that tomato was domesticated in America, the exact place of domestication has not yet been established (Abdullahi and Choji, 2009). The name tomato comes from the Nahuati language "xitomatl" of the Aztecs in Mexico which means the "plum thing".

2.1 Types of tomato fruits

Cherry Tomato – The term "cherry" usually refers to the shape and size of the fruit. Cherry tomatoes are small in size ranging from 12.5 mm to 16 mm in diameter and may be red or yellow in colour. The fruits are normally found in clusters and can produce on average of up to about 100 fruits per cluster. Owing to their bearing capacity, cherry tomatoes produce high yields per plant compared to other types of tomatoes. Most cherry tomatoes have high-climbing vines and the fruits of some have relatively tough skin. Vines can be staked, supported on trellises and/or pruned to two main stems and directed to strings or shoots (Jones *et al*., 1991; Franco *et al*., 2009).

Pear Tomato – As the name suggests, pear tomatoes are oval-shaped. Pear tomatoes also have small fruits which have nipples at the stem end of the fruit (Ku *et al*., 1999).

The vines of this type of tomatoes are similar to that of the cherry tomato in that they are tall and indeterminate but are lower in yield compared to the cherry tomatoes.

Plum and Peach tomatoes: - These types are similar to pear tomatoes but have no nipples. Fruits of all the three types of tomatoes can either be red or yellow with tender skins and juicy endocarp (Purseglove, 1974; Jones *et al*., 1991).

From a commercial point of view, tomato fruits can be classified into three groups according to their shape:

1. Round or spherical – these can further be grouped into round and cherry tomatoes where the latter is smaller.
2. Ribbed – this refers to tomatoes with well differentiated and pronounced ribs around the navel.
3. Oblong/elongated - these are tomatoes with an ovoid or ellipsoidal shape that may be elongated and have smoothed skins (OECD, 1988).

2.2 Uses of tomato

The tomato has many culinary uses. Whole tomatoes can be eaten raw as refreshment or as a dessert or cut into pieces and served in salads or sandwiches. The seeds contain about 24% oil which can be extracted and used in salads and also in the manufacture of margarine and soap, while the residue (press cake) is used as livestock feed and as organic fertilizer (Purseglove, 1974; Centre for Overseas Pest Research, 1983).

Gould (1992 cited in OECD, 2008) indicated that although consumers normally prefer to consume fresh tomatoes, more than 80% of the tomatoes that are consumed are in the processed form. However, it is worthy of notice that no matter the processing method, it is prudent that tomatoes used should be ripe and red in colour, and firm or soft but free from diseases, and dirt. Some of the forms into which tomato can be processed are:

Canned tomato, Tomato puree or pulp, Tomato paste: Tomato juice, Tomato squash, Tomato ketchup, Tomato powder, Tomato chutney.

2.3 Economic Importance of tomato

Tomato has contributed immensely to the *per capita* Gross Domestic Product (GDP) and export earnings of many countries worldwide including China, France, Greece, Israel, Italy, Portugal, Spain, Turkey and the USA. Owing to its importance as an export commodity, it has generated a lot of trade competition among some of these great nations.

Tomato production helps in improving the livelihood of growers especially in the tropics through income generation and therefore has a high priority among horticultural crops in these areas. Generally, tomato cultivation generates employment in rural areas; it stimulates urban employment, expands exports, improves nutrition and increases farmer‟s income (Villarreal, 1980).

As part of their economic importance, tomatoes and tomato products are vital to human nutrition, supplying folate, vitamin C, potassium, and more importantly, carotenoids (vitamin A precursors with antioxidant activity), the most important of which are lycopene and beta-carotene which protect the cells of the body from oxidative damage (Acedo and Thanh, 2006). A newly bred variety of tomato known as the "Purple Tomato" contains high amounts of anthocyanins which can help in fighting cancer in patients. Consumption of the fruit has been shown to extend the lifespan of cancer infected rats (Martin *et al*., 2008; Silvia *et al*., 2009). This assertion is supported by Sharoni and Levy (2007) who indicated that lycopene together with other carotenoids such as phytoene and phytofluene are effective in preventing the proliferation of cancer cells.

Lycopene is proved to be the strongest antioxidant (Saita and Vitatene, 2008) being 100 times stronger than α-tocopherol and making it instrumental in maintaining human health The benefits of lycopene on human health have and are continuously being explored with exciting results. For instance, studies have been conducted on its effects in the management of male infertility by reducing oxidative stress in spermatozoa (Mohanty, 2007); its effects on reducing blood pressure and preventing hypertension (Paran, 2007); its effects in protecting the skin from ultraviolet radiation (Stahi, 2007) and its role in the prevention of osteoporosis, a disease condition that leads to fragile bones especially at post-menopausal age in women
(Rao, 2007).

2.4 Constraints in tomato production

Production as well as postharvest constraints is relatively pronounced in developing countries. The production of tomatoes is constrained by factors such as lack of improved crop varieties, inadequate marketing systems, seasonal fluctuation in supplies and prices, inadequate research and, most importantly, postharvest losses known to cause up to about 30% of losses in these countries (Villareal, 1980).

2.5 Postharvest losses of tomato

Even though technologies such as development of improved varieties, improvement in the transport system, improvement in the quality and shelf-life of produce and improvement in production systems have been pursued for horticultural produce, the tomato industry, particularly in developing countries, still faces significant challenges at the postharvest level. This is due mainly to rough handling at the postharvest stage and improper storage conditions (Assi, 2005).

Postharvest losses can occur either in quantitative or in qualitative terms. These two major causes of losses occur between the farm gate and the table. It is estimated that about one-third of harvested fruits and vegetables do not reach the consumer as a result of these losses. In order to minimise the losses, it is important to understand the biological and environmental factors involved in postharvest deterioration, and to adopt the appropriate postharvest technology or procedures that will slow down deterioration and maintain quality and safety of the commodities (Kader, 2005).

2.6 Pre-harvest factors affecting the quality of horticultural crops

Pre-harvest factors that affect the quality and shelf-life of horticultural crops have been described by Lee and Kader (2000) as follows:

a. **Genotypic traits:** - certain crop varieties including tomato exhibit some inherent variations in nutrient composition, quality and shelf-life potential.

   These variations determine the latent quality of the postharvest condition of the produce. Examples are high carotenoids, sugars, acids, anthocyanins and vitamin A content in tomato. Additionally, some hybrid varieties have been bred where the rin and /or nor genes are incorporated in them to retard ripening and hence contribute to extending the shelf-life of these cultivars.

b. **Climatic conditions**: - the two most important climatic factors influencing the chemical composition of tomatoes are temperature and light intensity. These factors can affect the ascorbic acid content of the plant by their effects on photosynthesis from which sugars are broken down into ascorbic acid. Low temperatures reduce ascorbic acid synthesis while high light intensity increases it. On the other hand, high temperature is known to favour βcarotene at the expense of lycopene synthesis in tomato and hence results in light red or yellow colouration in the fruit. Since plants require water for their metabolic activity, the supply of water to the plant through the soil is influenced by rainfall and this can determine the dilution effect in the cells and hence the chemical composition of the harvested produce.

c. **Cultural practices**: - proper fertilisation and irrigation regimes increase crop yields. However, high nitrogen fertilizer and high water application rates tend to reduce vitamin C content and postharvest shelf-life of fruits and vegetables. On the other hand, a high calcium application improves storage life of the crop and confers support against physiological disorders such as blossom-end rot in tomatoes. The use of other agrochemicals such as pesticides also influences the chemical composition of horticultural commodities (Kader and Rolle, 2004; Thanh and Acedo, 2006).

2.7 Harvest factors affecting the quality of horticultural crops

The harvesting stage is a critical stage that determines the quality as well as the length of time the produce can be kept safely in storage without deterioration. It requires an expert acumen to determine the ideal stage to harvest such that the quality of the produce as well as its shelf-life is not compromised. In the absence of an expert advice, the produce can be harvested either too early or too late as to comprise its quality and postharvest life. Careless harvesting where the produce is thrown in collection bins causes mechanical damage. The damages manifested as bruises provide entry points for and invasion by disease-causing organisms during subsequent operations; it can also lead to loss of water and vitamin C. Tomatoes harvested overripe does not store for a long time as it deteriorates relatively faster while immature fruits fail to develop full colour and flavour, becomes shrivelled, deformed and deteriorates faster during storage (Bautista and Acedo, 1987 as in Acedo and Thanh, 2006). Acedo and Thanh (2006) identified four major

considerations that should be adhered to when harvesting tomato. These are: harvest maturity, time of harvest, harvesting method and field postharvest handling. Above practices are aggravated by pathological problems resulting from rotting by fungi or bacteria. High humidity conditions are conducive for microbial growth especially in produce damaged during harvesting and handling.

a. Losses due to physiological disorders

Physiological disorders involve tissue breakdown in the produce that may not be associated with disease or pest attack or mechanical damage. They may arise in response to pre-harvest conditions such as calcium deficiency or postharvest conditions such as freezing or chilling injury (Wills *et al*. 2007).

Examples of physiological disorders in tomato include:

Blossom end rot: - this is caused by calcium deficiency and is pronounced by irregular moisture supply. This is characterised by a water-soaked lesions at the blossom end of the fruit which later turn black as the spot increases (Gleason and Edmunds, 2006).

Chilling / heat injury: - chilling injury occurs as a result of storing tomatoes at temperatures below 12^oC while heat injury occurs above 32^oC. Chilling injury symptoms includes water-soaked spots and mottling while heat injury causes blotchy spots (Tan, 2005).

2.8 Magnesium and Calcium Effects on Growth of Pectomech and Tropimech

Aghofack-Nguemezi and Tatchago (2010) carried out an experiment to determine the effects of calcium and magnesium nutrients on the development of plants. Tomato plants were treated by applications of N/P/K (9.5/8/10) and fertilizers containing Ca^{2+} and/or Mg^{2+}. Control plants received only N/P/K. Two fertilizer combinations (N/P/K + foliar spray of Manvert Magnesium and N/P/K + calcium nitrate at 800 kg ha^{-1} + foliar spray of Manvert Magnesium) induced a significant delay in the flowering of plants.

Hao and Papadopoulos (2003) studied the effects of calcium and magnesium on growth in a fall greenhouse tomato crop grown on rockwool. Tomato (*Lycopersicon esculentum* Mill) „Trust" was grown onrockwool with two concentrations of calcium (150 and 300 mg L^{-1}) in combination with four concentrations of magnesium (20, 50, 80 and 110 mg L^{-1}) in fall, 1999, to investigate their effects on plant growth, leaf photosynthesis. High Ca concentration did not affect leaf photosynthesis. Plants grown at 20 mg L^{-1} Mg started to show leaf chlorosison both the middle and bottom leaves 8 wk after planting. Leaves with moderate chlorosis lost about 50% of their photosyntheticcapacity. The Mg concentration may be started at 50 mg L^{-1} and gradually increased to 80 mg L^{-1} towards the end of the season, to improve plant growth. Blossom-end rot (BER) incidence increased linearly with increasing Mg concentration in the early growth stage at low Ca, but BER incidence at high Ca was not affected by Mg concentration.

Park *et al.,* (2005) demonstrated that fruit from tomato (*Lycopersicon esculentum*) plants expressing Arabidopsis (*Arabidopsis thaliana*) H^+/cation exchangers (CAX) have more calcium (Ca^{2+}) and prolonged shelf-life when compared to controls. Previously, using the prototypical CAX1, it has been demonstrated that, in yeast (*Saccharomyces cerevisiae*) cells, CAX transporters are activated when the Nterminal auto inhibitory region is deleted, to give an N-terminally truncated CAX (sCAX), or altered through specific manipulations. To continue to understand the diversity of CAX function, they used yeast assays to characterize the putative transport properties of CAX4 and N-terminal variants of CAX4. CAX4 variants can suppress the Ca^{2+} hypersensitive yeast phenotypes and also appear to be more specific Ca^{2+} transporters than sCAX1. He then compared the phenotypes of *sCAX1*- and *CAX4*-expressing tomato lines. The *sCAX1*-expressing tomato lines demonstrate increased vacuolar H^+/Ca^{2+} transport, when measured in root tissue, elevated fruit Ca^{2+} level, and prolonged shelf-life but have severe alterations in plant development and morphology, including increased incidence of blossom-end rot. The *CAX4*expressing plants demonstrate more modest increases in Ca^{2+} levels and shelf-life but no deleterious effects on plant growth. These findings suggest that CAX expression may fortify plants with Ca^{2+} and may serve as an alternative to the application of $CaCl_2$ used to extend the shelf-life of numerous agriculturally important commodities. However, judicious regulation of CAX transport is required to assure optimal plant growth.

Rab and Haq (2012) investigated the influence of $CaCl_2$ and borax on growth, yield, and quality of tomato during the years 2009 and 2010. He layed the experiment out with a randomized complete block design. Calcium chloride (0.3% and0.6%) and borax (0.2% and 0.4%) solutions were applied as foliar sprays either alone or in combination and data was recorded for plant height, branches per plant, and flowers per cluster. The application of $CaCl_2$ alone significantly increased the plant height. Borax alone significantly enhanced the number of branches per plant, number of flowers per cluster. Foliar application of $CaCl_2$ (0.6%) + borax (0.2%) resulted in the maximum plant height (86.60 cm), branches per plant (7.21), flowers per cluster (32.36). However, the difference among 0.6% $CaCl_2$ + 0.2% borax, 0.3% $CaCl_2$ + 0.2% borax, and 0.6% $CaCl_2$ + 0.4%borax was not significant.

Olaniyi (2009) conducted experiments on a sandy loam soil at the Teaching and Research farm of the Faculty of Agricultural Sciences, Ladoke Akintola University of Technology (LAUTECH), Ogbomoso (8°10N; 4°10E) between April and July, 2004 to evaluate the growth of seven varieties of tomato in the Guinea Savannah zone of South West Nigeria. The varieties tested were, DT97/162A(R), DT97/215A, Tropical, Roma VF, UC82B, Ibadan local and Ogbomoso local. These were assigned randomly into three blocks each containing seven beds and fitted into randomized complete block design. Growth was assessed. The results showed that DT97/162A(R) gave the highest height whereas Ogbomoso local recorded the highest number of leaves at 6 weeks after transplanting.

The effect of partial replacement of KCl in the fertigation by KCl·$MgCl_2$ on growth of greenhouse tomato (cv. Durinta) was studied in a soil-less system. Forty-seven days after planting (DAP), three treatment solutions were applied to the plants using different K sources: (1) KNO3, (2) KCl, and (3) KCl·$MgCl_2$ Chapagain and Wiesman (2003) carried an experiment with + KCl (25%:75% in terms of K supplied). In both treatments 2and 3, NH4NO3, Ca (NO3)2 and HNO3 were added as source of N. He concluded that plant height and total chlorophyll were the highest in the KCl+KCl.$MgCl_2$ treatment. Leaf Mg content was significantly lower in the

KCl treatment, whereas highest in the KCl+KCl·$MgCl_2$ treatment. Both KCl and KCl+KCl·$MgCl_2$ led to a significantly higher leaf Cl content as compared with the KNO_3 treatment, but no Cl toxicity was observed in either treatment.

Ayyub *et al*. (2012) conducted field trial to investigate the effect of pre-harvest application of calcium chloride in tomato cv. Sahil. Different concentrations of calcium chloride (0.1, 0.2, 0.3, 0.4 and 0.5 M respectively) along with control were evaluated during the experiment. Control plants were sprayed with water without calcium chloride. A significant improvement in growth and yield of tomato fruit was observed with application of calcium chloride. The highest fruit set (69.3 %) was obtained with 0.5M calcium chloride (T6) along with maximum number of compound leaves per plant (40.33), maximum number of flowers. The results of the study indicated a positive correlation between plant growth and application of calcium chloride.

Upadhyay and Patra (2011) carried out an experiment to investigate the response of *Matricaria* to Calcium and Magnesium vis-à-vis the influence of the nutrients on growth in *Matricaria*. The effect of magnesium was found to be more pronounced as compared to calcium in respect of plant height, number of branches per plant, width of flower and number fresh weight (g) of flower. The growth parameters of *Matricaria* increased with increase in application rate of Calcium and Magnesium. The interaction effect of Calcium and magnesium at the rate of Ca 200+Mg 200mg pot-1 was maximum as compared to other combination resulting in the maximum plant height (60.5cm), number of branches per plant (70), number of flowers per plant (362), width of flower (2.66cm), fresh weight of flower per plant (26.94).

Chapagain and Wiesman (2003) reported on the effect of partial replacement of KCl in the fertigation by KCl-$MgCl_2$ on growth of greenhouse tomato (CV.Durinta) in soil-less system. Forty-seven days after planting (DAP), three treatment solutions were applied to the plants using different K sources (1) KNO3, (2) KCl, and (3) KClMg Cl2+KCl (25%:75% in terms of supplied). In both treatments 2 and 3, NH4 NO3, Ca (NO3)2 and HNO3 were added as source N. In this experiment, they concluded that plant height and total chlorophyll were the highest in the KCl+KCl.$MgCl_2$, led to a significantly higher leaf Cl content as compared with the KNO3 treatment, but no Cl toxicity was observed in either treatments. Although KCl as sole K source showed lower foliar Mg levels as compared to KNO3.

Taylor (2008) reported on the impacts of several calcium formulations applied throughout the peach fruit development and growth period. Calcium amono acid

Chelate (Metalosate Calcium), were assessed for, peach growth. Metaloate calcium was found to have caused increased in fruit size.

Arshi *et al.* (2012) conducted a study to assess the effects of NaCl (80 and 160 mm) and $CaCl_2$ (10 mm) solutions, alone and in combination, to 30-day-old seedlings of Cichorium intybus L. Observations were made at 30 day intervals from the time of treatment till harvest (180 days after sowing). Application of NaCl resulted in significant decreases in lengths of root and stem, in dry weights of root, stem and leaves and in the leaf area, as compared with control. The reduction was less with the combined application of NaCl and $CaCl_2$ than with the NaCl treatment alone. On the contrary, treatment of $CaCl_2$ alone promoted the above variables. Proline content in the leaves was enhanced with NaCl and $CaCl_2$ alone as well as with treatments, compared with NaCl (four-fold increase) and $CaCl_2$ (two-fold increase) alone. The sodium (Na+) and Chloride (Cl) contents in different plant parts increased both with NaCl and with NaCl + $CaCl_2$ treatments. The maximum accumulation was observed in leaves, followed by that in stem and root. The potassium (K+) and calcium (Ca2+) contents decreased under NaCl stress, but increased with $CaCl_2$ treatment. Thus, calcium ameliorated the deleterious effects of NaCl stress and stimulated the plant metabolism and growth.

Hao and Papadopoulos (2004) conducted a study to measure the effects of calcium and magnesium on growth, fruit yield and quality in a fall greenhouse tomato crop grown on rockwool. Their test crop (Tomato) "Trust" was grown on rockwool with nutrient solutions containing two levels of Calcium (150 and 300 $mg.L^{-1}$) in factorial combination with three levels of magnesium.(20,50 and 80 $mg.L^{-1}$) in winters 1997 and 1998 to investigate the effect of calcium and magnesium on growth, biomass partitioning and fruit production. Plants grown at 20 mg. L^{-1} Mg started to show Mg deficiency symptoms (leaf chlorosis) at 8 weeks after planting. The chlorophyll content of middle and bottom leaves increased with increasing Mg concentration in the nutrient solution. At 300 mg. L^{-1} Ca total fruit dry matter increased linearly with increasing magnesium concentrations; total plant biomass showed similar response but to lower degree.The biomass allocation to fruit increased while allocation to leaves decreased with increasing Mg. concentration. The appropriate Ca and Mg concentrations for tomato production appear to be at 300 and 80mg.L^{-1} respectively.

Al-Hamzawi (2010) conducted experiment during the period of December 2008 to May 2009 using cucumber (*Cucumis sativus* L. cv.Al-Hythum). Three concentrations of Anfaton; 0.00, 600 and 1000mg L^{-1} and five concentrations of spray solutions; 0.00mM (control), 10 and 15mM of Ca $(NO_3)_2$ and 10 and 15 Mm of KNO_3 in addition to the combination of anfaton and both concentrations of each spray solution were superior in their effect on plant vegetative characters. Maximum flower number was reported by the application of KNO_3, while maximum fruit set was obtained due to the use of anfaton at 1000mg L^{-1}. Dry weight increased due to spray with the two nutrients. All treatments significantly enhanced cucumber productivity especially at the higher concentration of anfaton and KNO_3. Nitrogen, Phosphorous, potassium and calcium content were recorded increased. The highest nitrogen percent and calcium content were recorded due to the use of 10 and 15 mM of $Ca(NO_3)_2$, respectively. Combination of the higher concentration of anfaton and higher concentration of nutrient revealed a pronounced effect in most of studied characters.

2.9 Magnesium and Calcium Effects on Yield of Pectomech and Tropimech

Hao and Papadopoulos (2003) studied the effects of calcium and magnesium on fruit yield in a fall greenhouse tomato crop grown on rockwool. High Ca (300 mg L^{-1}) concentration increased fruit yield and reduced the incidenceof blossom-end rot (BER) and fruit russeting, compared with the low Ca concentration (150 mg L^{-1}).

Tomato (*Lycopersicon esculentum* Mill) „Trust" was grown onrockwool with two concentrations of calcium (150 and 300 mg L^{-1}) in combination with four concentrations of magnesium (20, 50,80 and 110 mg L^{-1}) in fall, 1999, to investigate their effects on fruit yield.High Ca (300 mg L^{-1}) concentration increased fruit yield and reduced the incidenceof blossom-end rot (BER) and fruit russeting, compared with the low Ca concentration (150 mg L^{-1}). High Ca did not affect fruit size.Fruit yield in the late growth stage decreased at 20 mg L^{-1} Mg. Fruit russeting in midseason was affectedby nutrient treatments, being the least at 300/50 mg L^{-1} Ca/Mg. Therefore, for a fall greenhouse tomato crop, the optimum Ca/Mgconcentration for tomato production is estimated to be 300/50-80 mg L^{-1}. The Mg concentration may be started at 50 mg L^{-1} andgradually increased to 80 mg L^{-1} towards the end of the season, to improve fruit firmness.

Akhtar *et al.* (2010) conducted a study to evaluate comparative effects of sulphate and muriate of potash (SOP and MOP) application on yield of tomato (*Lycopersicon esculentum*, M. cultivar Roma) at National Agricultural Research Centre Islamabad, Pakistan. Potassium from two sources i.e., MOP and SOP was applied @ 0, 100 and 200 kg K ha-1 with constant dose of 200 kg N ha-1 and 65 kg P ha-1. A significant increase in tomato yield with K application was observed. Potassium applied @ 100 kg K ha-1 as MOP produced significantly higher marketable tomatoes as compared to SOP and control.

Nzanza (2006) concluded a green house experiment to investigate the effects of different Ca: Mg: K and K: Ca ratios on yield tomato. First, the trial regarding Ca: Mg ratios (20:1, 15:5, 10:10 and 12:8 mmolc. L^{-1} combined) with three levels of K concentrations (1, 6 and 9mmol1^{-1}) were applied to tomato plants growing in a sand coir mixture as growth medium. The experimental design was fully randomized design consisting four replications per treatment (Ca:Mg:K rates and ratios). In another trial, a factorial experiment which includes; two (2) that is (6 and 10 $mmol^{-1}$) and two Ca (12 and 16 $mmol^{-1}$) rates, given four (4) K:Ca ratios were used in water culture. High Ca: Mg ratios (20:1) in the nutrient solution decreases percentage class one fruits, and dry matter yields. As well, the study showed that only a Ca: Mg ratio of less than one can cause a significant reduction in yield. High K rates improved in percentage marketable fruits, increased levels of K rates did not affect fruit dry matter yields and percentage marketable fruits, but marketable dry matter yield was reduced, probably due to increased in BER incidence (at a low Ca: Mg ratios) with increased K rates.

California melon (*Cucumis melo*) growers commonly apply calcium (Ca) fertilizers during fruit development to increase fruit firmness and improve storage life. Dripirrigated field trials were conducted in central California in 2005 and 2006 to evaluate the efficacy of this practice on honeydew (*C. melo* Inodorus group) and muskmelon (*C. melo* Reticulatus group). In the 2005 honeydew trial, three weekly applications of 10 lb/acre Ca from calcium nitrate (CN), calcium thiosulfate (CTS), or calcium chloride (CC) were injected into the irrigation system during early melon development. In the 2006 muskmelon trial, two applications of 15 lb/acre Ca from CTS or CC were made early, or two applications of CC late, in melon development. The effect of these Ca fertigation treatments on fruit yield were compared with an untreated control receiving no Ca fertigation. Calcium fertigation had no effect on marketable yield or Ca concentration of honeydew or muskmelon fruit regardless of application timing or Ca source applied. Concluded that under conditions representative of the California melon industry, Ca fertigation at typical application rates is ineffective in improving honeydew or muskmelon yield (Johnstone12008).

Fanasca (2012) investigated the effect of cationic proportions (K/Ca/Mg) in the nutrient solution non fruit quality (quality attributes and antioxidant content) using a high pigment, Lunarossa, tomato cultivar and as standard tomato cultivar („Corfu) grown in soilless culture. Treatments were defined by a factorial combination of three nutrient solutions having different cationic proportions and two indeterminately growing round tomato cultivars. He concluded that a high proportion of Ca improved tomato fruit yield and reduced the incidence of blossom-end rot (BER). The highest total antioxidant activity was observed in the treatment with a high proportion of Mg in the Lunarossa cultivar.

Rab and Haq (2012) investigated the influence of $CaCl_2$ and borax on growth, yield, and quality of tomato was investigated during the years 2009 and 2010. He layed the experiment out with a randomized complete block design. Calcium chloride (0.3% and

0.6%) and borax (0.2% and 0.4%) solutions were applied as foliar sprays either alone or in combination and data was recorded for fruits per plant, yield, and fruit weight. The application of $CaCl_2$ alone significantly increased the fruits per plant, fruits per cluster, fruits per plant, fruit weight. Foliar application of $CaCl_2$ (0.6%) + borax (0.2%) resulted in the maximum fruits per plant (96.37), fruit weight (96.33 g), yield (21.33 t ha–1). However, the difference among 0.6% $CaCl_2$ + 0.2% borax, 0.3% $CaCl_2$ + 0.2% borax, and 0.6% $CaCl_2$ + 0.4%borax was not significant.

Olaniyi (2009) conducted experiments on a sandy loam soil at the Teaching and Research farm of the Faculty of Agricultural Sciences, Ladoke Akintola University of Technology (LAUTECH), Ogbomoso (8°10N; 4°10E) between April and July, 2004 to evaluate the growth, fruit yield and quality of seven varieties of tomato in the Guinea Savannah zone of South West Nigeria. The varieties tested were, DT97/162A(R), DT97/215A, Tropical, Roma VF, UC82B, Ibadan local and Ogbomoso local. These were assigned randomly into three blocks each containing seven beds and fitted into randomized complete block design. Yield of tomato was assessed. Higher fruit yield was recorded from UC82B, closely followed by Ibadan and Ogbomoso local. Although, there is inconsistence in the results of the nutritional compositions of tomato fruits, the local varieties (Ogbomoso and Ibadan Local) closely followed by UC82B recorded most of the nutritional values more than the other varieties. Therefore UC82B, Ibadan and Ogbomoso local in that descending order are better in terms of fruit yield and can be successfully grown in Ogbomoso, the Guinea Savannah zone of south west Nigeria.

The effect of partial replacement of KCl in the fertigation by KCl·$MgCl_2$ on yield of greenhouse tomato (cv. Durinta) was studied in a soil-less system. Forty-seven days after planting (DAP), three treatment solutions were applied to the plants using different K sources: (1) KNO3, (2) KCl, and (3) KCl·$MgCl_2$ Chapagain and Wiesman (2003) carried an experiment with + KCl (25%:75% in terms of K supplied). In both treatments 2and 3, NH4NO3, Ca (NO3)2 and HNO3 were added as source of N. Total yield was not different among treatments.

Ayyub *et al*. (2012) conducted field trial to investigate the effect of pre-harvest application of calcium chloride in tomato cv. Sahil. Different concentrations of calcium chloride (0.1, 0.2, 0.3, 0.4 and 0.5 M respectively) along with control were evaluated during the experiment. Control plants were sprayed with water without calcium chloride. A significant improvement in yield of tomato fruit was observed with application of calcium chloride. The highest fruit set (69.3 %) was obtained with 0.5M calcium chloride (T6), number of fruits per plant (95.33) and fruit weight per plant (6.00 kg). Yields were adversely affected at 100 % and 40 % of the field capacity.

Upadhyay and Patra (2011) carried out an experiment to investigate the response of *Matricaria* to Calcium and Magnesium vis-à-vis the influence of the nutrients on yield of *Matricaria*. He set a varying levels Ca comprising (0, 50, 100, 150 and 200 mg pot-1 having kg soil) to elucidate yield parameters and oil yield of *Matricaria* during rabi season of 2009-10 at Central Institute of Medical and Aromatic Plants, Lucknow. The yield parameters of *Matricaria* increased with increase in application rate of Calcium and Magnesium. The conjoint application of Ca and Mg both at the rate of 200mg pot L^{-1} (C5M5) significantly influenced the yield, yield contributing character and oil content (1.10%) as compared to the rest of the treatments. Mehdi *et al. (*2008) through research investigated the effects of some macro and micro nutrients on fruit quality and quantity in (Barberris Vulgaris L.) plants. Treatment included Manganese (Mn20 and 40mg. L^{-1}), Potassium (K1 and 2%), Ca (Ca2 and 3%) boron (B.2000mg. L^{-1}), Zinc (Zn300 and 600mg L^{-1}) and Water (W). Per the outcome of the findings, they concluded that the highest and lowest yields were being obtained by W and Ca 2%, respectively. The results of these studies showed that mineral nutrients via spray can alter the yield barberry fruits.

Taylor (2008) reported on the impacts of several calcium formulations applied throughout the peach fruit development period. Calcium amono acid Chelate (Metalosate Calcium), were assessed for their effect oncracking and reduced postharvest fruit rots. Metaloate calcium was found to have caused increased in fruit size.

In order to study the effect of calcium borate and micronutrients on some characters of apple Sheikh Amir Variety fruits, Ahmad and Mahdi (2012) conducted an experiment during 2010 and 2011 seasons cropping season in apple orchard at Shirvan region. The experimental design in this research was randomized complete block design (RCBD) with four replications. The treatments were comprised of three levels of Pre-harvest foliar application of nutrients T1 = Control (water foliar application), T2 = Micronutrient foliar application T3 = T2 + calcium borate 0.5% foliar application. They concluded per the results that the use of micronutrient and

Calcium borate in foliar application method had significant effect on fruits yield. Among all measured characters high amount of fruits yield was recorded in calcium borate treatment.

Hao and Papadopoulos (2004) conducted a study to measure the effects of calcium and magnesium on fruit yield in a fall greenhouse tomato crop grown on rockwool.

Their test crop(Tomato) "Trust" was grown on rockwool with nutrient solutions containing two levels of Calcium (150 and 300mg.L^{-1}) in factorial combination with three levels of magnesium.(20,50 and 80 mg.L^{-1}) in winters 1997 and 1998.to investigate the effect of calcium and magnesium on fruit production. Plants grown at 20 mg. L^{-1} Mg started to show Mg deficiency symptoms (leaf chlorosis) at 8 weeks after planting. At 300 mg.L^{-1} Ca total fruit yield and fruit dry matter increased linearly with increasing magnesium concentrations; marketable fruit yield showed similar response but to lower degree. At 150 mg. L^{-1}Ca, total plant biomass, fruit dry matter yield peaked at 50mg. L^{-1} Mg. Mg effect on total and marketable fruit yield were mainly due to its influence on fruit yield in the late growth stage.

2.10 Magnesium and Calcium Effects on Postharvest Quality of Pechtomech and Tropimech

Aghofack-Nguemezi and Tatchago (2010) carried out an experiment to determine the effects of calcium and magnesium nutrients on the subsequent postharvest conservation of tomato fruits. Combinations of soil applications of N/P/K and calcium nitrate at 200 kg ha^{-1} with foliar sprays of Manvert Calcium and/or Manvert Magnesium led to significant increases in the content of Ca^{2+} in mature-green fruits and subsequently to the delay of their ripening and the prolongation of the conservation period. Combinations of N/P/K + calcium nitrate at 200 kg ha^{-1} + Manvert Magnesium and N/P/K + calcium nitrate at 400 kg ha^{-1} + Manvert Calcium + Manvert Magnesium led to significant increases in the Mg^{2+} content in fruits. Fruits produced by plants that received these fertilizer combinations also showed a prolongation of the duration of ripening period and that of the conservation. The longest **shelf-life** was obtained after simultaneous applications on soil of N/P/K and calcium nitrate at 200 kg ha^{-1} and foliar sprays of Manvert Calcium and Manvert Magnesium. These results indicated that calcium and magnesium could be considered as key elements of fertilizers with regard to the delay of ripening of mature-green tomato fruits and to the prolongation of the **shelf-life** of the red-ripe ones.

Hao and Papadopoulos (2003) studied the effects of calcium and magnesium on fruit quality in a fall greenhouse tomato crop grown on rockwool. Tomato (*Lycopersicon esculentum* Mill) „Trust" was grown onrockwool with two concentrations of calcium (150 and 300 mg L^{-1}) in combination with four concentrations of magnesium (20, 50, 80 and 110 mg L^{-1}) in fall, 1999, to investigate their effects on fruit quality (fruitfirmness, dry matter, soluble solids and russeting). High Ca (300 mg L–1) concentration reduced the incidenceof blossom-end rot (BER) and fruit russeting, compared with the low Ca concentration (150 mg L^{-1}). High Ca concentrationreduced fruit firmness but did not affect fruit size.Fruitfirmness increased with increasing Mg concentration at low Ca. At high Ca, Mg concentration affected fruit firmness only late in theseason; fruit firmness at 80 mg L^{-1} Mg was higher than at 50 mg L^{-1} Mg concentration. Fruit russeting in mid-season was affectedby nutrient treatments, being the least at 300/50 mg L^{-1} Ca/Mg. Therefore, for a fall greenhouse tomato crop, the optimum Ca/Mgconcentration for tomato production is estimated to be 300/50-80 mg L^{-1}. The Mg concentration may be started at 50 mg L^{-1} andgradually increased to 80 mg L^{-1} towards the end of the season, to improve fruit firmness.

Akhtar *et al.* (2010) conducted a study to evaluate comparative effects of sulphate and muriate of potash (SOP and MOP) application on chemical composition and quality of tomato (*Lycopersicon esculentum,* M. cultivar Roma*)* at National

Agricultural Research Centre Islamabad, Pakistan. Potassium from two sources i.e., MOP and SOP was applied @ 0, 100 and 200 kg K ha-1 with constant dose of 200 kg N ha-1 and 65 kg P ha-1. Levels and sources of potassium showed no effect on acidity of tomato fruits. Potash application decreased sugar content of tomato fruits as compared to control. This effect of K on reducing sugar content was more pronounced in K treated fruits as SOP than those of MOP. Vitamin C contents in tomato fruits increased with K application in the form of MOP. The K use as MOP significantly reduced incidence of leaf blight disease and insect pest attack in tomato plant as compared to SOP and control treatments.

Nzanza (2006) concluded a green house experiment investigated the effects of different Ca: Mg: K and K: Ca ratios on quality tomato. First, the trial regarding Ca:

Mg ratios (20:1, 15:5, 10:10 and 12:8 mmolc. 1^{-1} combined) with three levels of K concentrations (1, 6 and 9mmol1^{-1}) were applied to tomato plants growing in a sand coir mixture as growth medium. The experimental design was fully randomized design consisting four replications per treatment (Ca:Mg:K rates and ratios)In another trial, a factorial experiment which includes; two(2)that is (6 and 10 $mmol^{-1}$) and two Ca (12 and 16 $mmol^{-1}$) rates, given four(4) K:Ca ratios were used in water culture. High Ca: Mg ratios (20:1) in the nutrient solution decreases tomato fruit pH, titratable acidity (TA), total soluble solids (TSS). As well, the study showed that only a Ca: Mg ratio of less than one can cause a significant reduction in fruit quality. High K rates yielded higher fruit quality parameters (PA, TSS, and TA)

California melon (*Cucumis melo*) growers commonly apply calcium (Ca) fertilizers during fruit development to increase fruit firmness and improve storage life. Dripirrigated field trials were conducted in central California in 2005 and 2006 to evaluate the efficacy of this practice on honeydew (*C. melo* Inodorus group) and muskmelon (*C. melo* Reticulatus group). In the 2005 honeydew trial, three weekly applications of 10 lb/acre Ca from calcium nitrate (CN), calcium thiosulfate (CTS), or calcium chloride (CC) were injected into the irrigation system during early melon development. In the 2006 muskmelon trial, two applications of 15 lb/acre Ca from CTS or CC were made early, or two applications of CC late, in melon development. The effect of these Ca fertigation treatments on soluble solids concentration, flesh firmness, and Ca concentration were compared with an untreated control receiving no Ca fertigation. Calcium fertigation had no effect on quality, or Ca concentration of honeydew or muskmelon fruit regardless of application timing or Ca source applied. Loss of firmness during either 2 weeks (honeydew) or 1 week (muskmelon) of postharvest storage was unrelated to Ca fertigation treatment and was not correlated with Ca concentration in fruit tissue. They concluded that under conditions representative of the California melon industry, Ca fertigation at typical application rates is ineffective in improving honeydew or fruit quality (Johnstone1, 2008). The aim of this study was to investigate the effect of cationic proportions (K/Ca/Mg)

in the nutrient, Fanasca (2012) investigated the effect of cationic proportions(K/Ca/Mg) in the nutrient solution non fruit quality (quality attributes and antioxidant content)b using a high pigment, „Lunarossa, tomato cultivar and as standard tomato cultivar („Corfu) grown in soilless culture. Treatments were defined by a factorial combination of three nutrient solutions having different cationic proportions and two indeterminately growing round tomato cultivars. He concluded that a high proportion of K in the nutrient solution increased the quality attributes (fruit dry matter, total soluble solids content) and the lycopene content of tomato fruit, whereas a high proportion of Ca reduced the incidence of blossom-end rot (BER). The highest total antioxidant activity was observed in the treatment with a high proportion of Mg in the Lunarossa cultivar. The high-pigment hybrid has provided higher antioxidant content (lycopene and R-tocopherol content) than the commercial hybrid, but it was more susceptible to BER and consequently less productive.

Rab and Haq (2012) investigated the influence of $CaCl_2$ and borax on growth, yield, and quality of tomato was investigated during the years2009 and 2010. He layed the experiment out with a randomized complete block design. Calcium chloride (0.3% and0.6%) and borax (0.2% and 0.4%) solutions were applied as foliar sprays either alone or in combination and data was recorded for fruit firmness, and total soluble solid (TSS) content of the fruit. The application of $CaCl_2$ alone significantly decreased the incidence of blossom end rot (BER). Borax alone significantly enhanced fruit weight, fruit firmness, and total soluble solid (TSS) content of the fruits. Foliar application of $CaCl_2$ (0.6%) + borax (0.2%) resulted in the maximum fruit firmness (3.46 kg cm–2), and total soluble solids (TSS) (6.10%) and the lowest blossom end rot incidence (6.25%). However, the difference among 0.6% $CaCl_2$ + 0.2% borax, 0.3% $CaCl_2$ + 0.2% borax, and 0.6% $CaCl_2$ + 0.4%borax was not significant.

Awanget *al*., (2011) conducted this research to examine the effects of $CaCl_2$ postharvest treatment on development of anthracnose, measured as lesion size and quality of red-flesh dragon fruit (*Hylocereus polyrhizus*). Fully matured fruits were treated with varying concentrations of Ca by soaking the fruits for 30 min in solutions containing 0, 1.0, 2.0, 3.0 and 4.0 $CaCl_2$ g L^{-1}. After drying, the fruits were inoculated with spore suspensions of *Colletotrichum gloeosporioides* (106 spores L^{1}). Calcium chloride applied at varying concentrations did not produce significant effect on anthracnose incidence, but the size of lesion was linearly reduced with increasing Ca concentration. Calcium chloride application as postharvest treatment markedly elevated fruit Ca content especially in the fruit peel, but without influencing the N, P, K and Mg contents. Fruit firmness increased with Ca application while pH, soluble solids concentration and titratable acidity were not affected by the treatment. The effect of anthracnose on firmness, pH, SSC and TA of the fruits were reduced with $CaCl_2$ treatments he concluded.

Nahar and Gretzmacher (2002) conducted a study to investigate the influence of water stress on tomato plants and fruit quality in a pot experiment (Bangladesh). Dry matter production was adversely affected at 100 % and 40 % of the field capacity. The uptake of nitrogen, sodium, potassium, sulphur, calcium and magnesium were significantly reduced by water stress in the plants. Significant increases in glucose, fructose and sucrose in fruits and proline content in leaves showed some tendency of this crop to adjust osmotically to water stress. Water stress increased the sugar and acid contents (ascorbic, malic and citricacid) of the tomato fruits and thus improved the fruit quality. Upadhyay and Patra (2011) carried out an experiment to investigate the response of *Matricaria* to Calcium and Magnesium vis-à-vis the influence of the nutrients on quality of essential oil in *Matricaria*. He set a varying levels Ca comprising (0, 50,100,150 and 200mg pot-1 having kg soil) to elucidate quality of Matricaria during raiiny season of 2009-10 at Central Institute of Medical and Aromatic Plants, Lucknow. The combination also resulted in the best quality of oil with respect to chemical constituents.

Mehdi *et al. (*2008) through research investigated the effects of some macro and micro nutrients on fruit quality and quantity in (Barberris Vulgaris L.) plants. Treatment included Manganese (Mn20 and 40mg. L^{-1}), Potassium (K1 and 2%), Ca (Ca2 and 3%) boron (B.2000mg. L^{-1}), Zinc (Zn300 and 600mg L^{-1}) and Water (W).

Although high amount of vitamin C was resulted from Ca treatments, high concentration of TA and SSC were found in K treatments. The results of these studies showed that mineral nutrients via spray can alter the quality of barberry fruits.

Taylor (2008) reported on the impacts of several calcium formulations applied throughout the peach fruit development period. Calcium amono acid Chelate (Metalosate Calcium), were assessed for their effect on the quality and shelf life of peach fruit firmness, cracking and reduced postharvest fruit rots. Metaloate calcium was found to have caused increased in fruit size.

Ahmad and Mahdi (2012) studied the effect of calcium borate and micronutrients on some characters of apple Sheikh Amir Variety fruits, an experiment was conducted during 2010 and 2011 seasons cropping season in apple orchard at Shirvan region. The experimental design in this research was randomized complete block design (RCBD) with four replications. The treatments were comprised of three levels of Preharvest foliar application of nutrients T1 = Control (water foliar application), T2 = Micronutrient foliar application T3 = T2 + calcium borate 0.5% foliar application. They concluded per the results that the use of micronutrient and Calcium borate in foliar application method had significant effect on fruit firmness, total soluble solids (Brix index), acidity and fruit concentration of B and Ca after harvest. Among all measured characters high amount of fruit firmness, total soluble solids and fruit concentration of B and Ca was recorded in calcium borate treatment but maximum amount of fruit acidity was obtained in control treatment.

Hao and Papadopoulos (2004) conducted a study to measure the effects of calcium and magnesium on quality in a fall greenhouse tomato crop grown on rockwool.

Their test crop (Tomato) “Trust” was grown on rockwool with nutrient solutions containing two levels of Calcium (150 and 300mg.L^{-1}) in factorial combination with three levels of magnesium.(20,50 and 80 mg.L^{-1}) in winters 1997 and 1998 to investigate the effect of calcium and magnesium on, biomass partitioning. At 300 mg.L^{-1} Ca total fruit dry matter increased linearly with increasing magnesium concentrations; marketable fruit yield and total plant biomass showed similar response but to lower degree. At 150 mg. L^{-1}Ca, total plant biomass, fruit dry matter yield peaked at 50mg.L-1 Mg. The biomass allocation to fruit increased while allocation to leaves decreased with increasing Mg. concentration. Incidence of Blossom-end rot (BER) at 150 mg.L^{-1} Ca increased linearly with increasing Mg concentrations at 300mg.L^{-1}Ca. For a winter greenhouse tomato crop, the appropriate Ca and Mg concentrations for tomato production appear to be at 300 and 80mg.L^{-1} respectively.

Al-Hamzawi (2010) conducted experiment during the period of December 2008 to May 2009 using cucumber (*Cucumis sativus* L. cv.Al-Hythum). Three concentrations of Anfaton; 0.00, 600 and 1000mg L^{-1} and five concentrations of spray solutions; 0.00mM (control), 10 and 15mM of $Ca(NO_3)_2$ and 10 and 15 Mm of KNO_3 in addition to the combination of anfaton and both concentrations of each spray solution. Dry weight increased due to spray with the two nutrients. All treatments significantly enhanced cucumber productivity especially at the higher concentration of anfaton and KNO_3. Nitrogen, Phosphorous, potassium and calcium content were recorded increased. The highest nitrogen percent and calcium content were recorded due to the use of 10 and 15 mM of $Ca(NO_3)_2$, respectively. Combination of the higher concentration of anfaton and higher concentration of nutrient revealed a pronounced effect in most of studied characters. Potassium nitrate at both concentrations was the best in keeping the total soluble solid (TSS) at a higher levels. Also, all nutrients treatments reduced electrolyte leakage from fruits compare to control especially the $Ca(NO_3)_2$ treatments.

CHAPTER 3

MATERIALS AND METHODS

3.0 Experimental design

Bulk soil sample was taken (0-20 cm and 20-40cm) before treatment application. Lime and $MgSO_4$ were broadcast and hoed-in 2 weeks before transplanting. Other agronomic practices were conducted as usual.

In the field the materials used were; pegs, auger, garden line, tape measure, wheelbarrow, watering cans, water tank, water hose and water pumping machine. In the laboratory however materials used in this experiment included varieties of tomatoes which were pectomech and tropimech. The rest were instruments which also includes refractometer, pipette, filter, distilled water, hydrometer, and laboratory blender. Measuring cylinder, conical flasks, beakers, electric oven analytical scale, digital scale, spatula pippet burette, knife, digital venier calliper, chopping board,

0.1M sodium hydroxide (NaOH), phenolphthaein as an indicator and sieve.

KNUST

3.1 Site Description

The experiment was conducted at Central Agricultural Station (CAS), Kwadaso, at CSIR-Soil Research Institute experimental fields (06^0 43‟ N, 01^0 36‟ W) at an altitude of 28.71m above sea level. The area has a bimodal rainfall with major and minor seasons in March to July and September to November respectively. The mean annual rainfall is 1100mm. The mean temperature ranges between 24°C and 27°C.

The soils in the area belong to the Kumasi- Asuansi Soil Association (Ghana Soils Classification) or Ferric Acrisol-Dystic Fluvisol (ISSS/ISRIC/FAO, Soil Classification, 1998).

3.2 Soil sampling

Initial soil samples were taken (0-20cm) before treatment application. Soil sampling was done per plot at harvest. Soil samples were brought to Soil Research Institute laboratory and air-dried at room temperature. The air-dried soil samples were ground and passed through 2 mm sieve. Soil pH was measured using a glass electrode (pH meter) in a soil to water ratio of 1:2.5 (Mclean, 1992). Organic carbon was determined by the wet combustion method as described by Walkley and Black (1934).

Exchangeable cations (Ca, Mg, and K) were extracted with 1.0M ammonium acetate solution and determined by atomicabsorption spectrometry (Thomas, 1982).

3.3 Soil analysis

An area measuring 75 x 20 m was demarcated for the experiment. The field was ploughed and harrowed. A total of 48 plots in four blocks were layed and assigned randomly. Each block had 12 plots sub divided into 2 of six plots each and fitted into Randomise Complete Block Design (these constituted the main treatments containing the 2 tomato varieties). The 6 plots were also sub-devided into 2 of 3 plots each constituting the sub-sub plots containing lime or no lime treatments. The different rates of $MgSO_4$ were applied on the 3 sub-sub plots. Initial soil samples were taken (0-20 cm and20-40cm) with an auger before the field layout was done. Soil sampling was also done per plot at harvest. Soil samples were sent to Soil Research Institute and air-dried at room temperature. Air-dried soil samples were ground and passed through 2 mm sieve. Soil pH was measured using a glass electrode (pH meter) in a soil: water ratio of 1:2.5 according to the method recommended by Mclean (1982).

Organic matter was determined by the wet combustion method (Walley and Black, 1934). Total nitrogen by micro khajedal method (Bremmer and Mulvaney, 1982). Available phosphorus was determined by the method of Bray and Kurtz (1945). Exchangeable cations (Ca, Mg, K) were extracted with 1.0 M ammonium acetate solution and their levels determined by atomic absorption spectrometry (IITA, 1979).

3.4 Data collection

3.4.1 Determination of the stem diameter, Height, canopy spread and leaf area

The stem diameter and height of plants and leaf area were measured at the sixth week after transplanting. The height was measured from the base of the plant up to the last growing point. At harvest, the diameters of fruits were also measured both laterally and longitudinally. The measurement of the diameter was done using a digital vernier caliper. The diameter of the stem was measured at the level of 5 and10 cm from the ground. Canopy was measured by taking the gird of the plant laterally at its rest or natural position and it was done by meter rule.

The digital caliper was used to determine the external stem diameter and also the leaf area of the tomato plant. Length and breadth of the leaves were measured from each plant randomly and the average also known as means were used to calculate the area hence leaf area.

The formula used was: Leaf Area =Length × Breadth.

3.5 Firmness

Firmness of the tomato fruit was measured with a hand held penetrometer in accordance with the OECD standards.

3.6 Determination of Fruit Acids by Titration and Calculation of the Sugar/Acid Ratio

3.6.1 Method using a coloured indicator

This was the method employed for the experiment. Three (3) drops of phenolphthalein were added to the juice/water solution in each beaker from a dropping pipette which was specifically kept for that purpose. It was ensuredthat the tap on the burette was shut and using a funnel poured the 0.1M solution of NaOH into the burette until it reached the zero mark. NaOH was slowly titrated into the juice/water solution (with a 25ml burette or an automatic burette). Care was taken to ensure that the NaOH was dropped directly into the solution and did not adhere to the glass this was achieved through thorough washing and rinsing for accuracy; otherwise the readings could have been false. While titrating, care was taken to continually but gently swirl the solution in the beaker to keep it thoroughly mixed. This was highly essential, particularly when the solution nears neutrality. It is important to determine the point of neutrality or the end point of titration very exactly. The phenolphthalein indicator changes very rapidly from colourless to pink and the end point can easily be missed, which will give an inaccurate reading for the test. It is important therefore that; towards the end of the titration the NaOH is added a drop at a time. Using phenolphthalein as an indicator, the point of neutrality is reached when the indicator changes from colourless to pink. The indicator colour must remain stable (persisting for 30 seconds) and be light pink when viewed over a white background. However, the shade can vary depending on the type of juice was

tested.

3.7 Determination of Dry Matter Content by microwave-Oven Quick Method

The percent dry matter was obtained in an oven at 70°C until consecutive weightings was made at 2h intervals vary by less than 3 mg (AOAC Methods 1980).

3.8 Determination of water content in fruit and estimation of crop yield

Fresh tomato fruits were weighed and dried in an oven successively at 65 and 105^{o}C for 4 days hours respectively. They were then weighted for the determination of dry matter weight according to Chapman (1976). The crop yield was obtained by calculating the total fresh weight of tomato fruits harvested in all the plots that received the same treatment as it were.

3.9 Determination of Diameter, Leaf Area and Heights

The diameter/canopy spread and height of plants were measured at 50% flowering. The height was measured from the ground at the surface of the soil immediately above the ground at the collor of the plant upwards. The diameter of the stem was measured at two levels, that is 5cm and 10cm and average of these measurements were calculated for that matter thereof. Length and breadth of the leaf were measured for the actual leaf area and at random, the smallest through medium to biggest were selected and measured. At harvest, the diameter of the fruits was also measured both laterally and longitudinally. The measurement was done with the help of digital caliper.

3.10 Determination of the Number of Days after transplanting out required for the Flowering of 50% of Plants and of the Percentage of Abortion of Floral Buds and Flower

The time in days passed between the transplanting of seedlings and the flowering of 50% of plants in each plot was recorded.

3.11 Determination of Calcium and Magnesium in Tomato Samples

3.11.1 Extraction

The various samples of the tomatoes were dried and milled into powder and sieved through 2mm sieve after which 10g of the sieved tomato powder was weighed into an extraction bottle. After that, 100 ml of 1.0 N NH_4O solution was then added. After that also, the bottle was then placed with its content in a mechanical shaker and shook for one hour. After all these, the supernatant solution was then sieved through No 42 Whatman filter paper. And finally, the aliquots of the filtrate (extract) were then used for the determination of Ca, Mg, K and Na.

3.11.2 Titration of calcium (Ca)

To a 10ml aliquot of the sample solution extracted and filtered, 10ml of 10% KOH solution was then added followed by 1 ml of 30% Triethanolamine. 3 drops of 10% KCN solution was also added together with a few crystals of Cal-red indicator and shook vigorously to achieve uniform mixture. The mixture was then titrated with 0.02 N EDTA solutions from a red to blue endpoint.

3.11.3 Titration of calcium plus magnesium (Ca+Mg)

To a 10ml aliquot of the same sample solution above was put into a 100ml conical flask and added 5ml of ammonium chloride-ammonium hydroxide buffer solution followed by 1ml of triethanolamine. 3 drops of 10% KCN solution and a few drops of EBT indicator solution were also added and shaking was done vigorously and thoroughly for uniform mixture before use. The mixture was titrated with 0.02 N EDTA solutions from a red to blue endpoint.

3.11.4 Calculation

To determine the value for Mg only: the value for Ca was subtracted from that of the Ca+Mg

Thus, Titre value for [(Ca+Mg) – Titre value for (Ca)] x 2 = Mg Cmo//kg

NB: Ca = Titre value of Ca x 2 in Cmol/kg or me/100g soil

Fresh fruits were dried in an oven at 30^{o}C for 24hours. One gram of the dried samples was calcined at 2^{o}C for 24 hours. Ten milliliter of 1Nitric acid solution was added to the ash and the mixture was heated till the evaporation of half of volume.

The residue was completed to 50mL with distilled water. The solution was further threefold diluted before use. Ca2+ contents were determined by the complexometric method as described by Pauwels *et al*. (1992).

3.12 Determination of total soluble solids (TSS)

Whole fruits were diced, chopped and further blended into paste and subsequently sieved with a calico. The juice resulting from this process was dropped and spread over a surface of a refractometer (QA supplies-R305846) prism plate. The reading on the prism scale was noted and recorded to that effect when observed through the peep hole of the prism to a source of light. The surface of the prism plate was thoroughly cleaned with distilled water and subsequently wiped with a tissue to pave way for next test. The procedure was repeated 3 times per each treatment and conducted on all the 4 stages of breaker, half, full and red ripped. In all, this was the basis on which the TSS was being conducted (OECD, 1999).

3.14 Determination of pericap thickness

Three fruits from each treatment were randomly selected and asymmetrically splited and one half was taken for examination. The peri-cap thickness was conducted and measured three times each per fruit and nearly opposite in position to one another. The caliper was first closed and set to zero. The outer was then opened and tightly closed to touch the pericap from both side such that one edge of the caliper was inside the fruit where as the other part of the caliper was outside the fruit and invariably sandwich the pericap and the readings on the number plate was then recorded as thickness per that pericap. The process was uniformly done tightly to the pericap. This was done with the help of digital caliper. Again, the averages were calculated per fruit for final peri-cap thickness.

3.15 Moisture content

Moisture content was determined by weighing petri dish after which a slice of fruit was added and also weighed. The petri dish together with the fruit slice was then oven dried after which it was weighed again, this was repeated until there was a stable figure. The resulting figure from that was then subtracted from the dried slice weight and the moisture content was then obtained and percentage of it determined. The process was repeated on all the 4 stages of ripening. The percentage of moisture content was calculated and determined by formula:

$$\text{Moisture content} = \frac{(\text{Fresh Weight} - \text{Weight after drying})}{\text{Fresh Weight}} \times 100$$

Where the fresh weight is the weight minus the petri dish before drying and the weight after drying. This was being conducted for the different stages of ripening. The percentage dry matter content was also calculated using the formula as shown below:

$$\text{Dry Matter} = \frac{\text{Dry Weight} \times 100}{\text{Fresh Weight}}$$

3.16 Total titrable acidity (TTA)

10 ml of fruit was diluted with 50ml of distilled water and titrated against 0.1NaOH. This was done three times for each replication and titratable values were recorded. The average was then taken and used.

The average titratable values were converted to indicate the total titrable acid (Malic acid) using the formula below:

$$\text{Grams/liter acid} = \frac{\text{Titre} \times \text{acid factor} \times 100 \times 10}{10(\text{ml juice})}$$

The acid factor is 0.0067 for malic acid which is dominant acid in tomatoes (OECD).

3.17 Determination of shelf life

The weighing of fruits were being done individually with the help of analytical scale/grams till they were finally considered unfit for consumption or usable or for sale.

CHAPTER 4

RESULTS

4.1 Soil Analysis before and after Treatment

From the results (Table 4.1), different magnesium rates with no lime showed no increase in soil pH. There was, however, an increase in pH when the soil was treated with both lime and magnesium. An increase in magnesium content after treating with only magnesium as well as magnesium in combination with lime was also observed. Potassium levels were also not affected by the application of calcium and magnesium and phosphorous content decreased in the soil after cropping. On the other hand, the content of organic matter increased after cropping.

Table 4.1: Selected soil properties before treatment application and after harvest

Selected soil properties	Initial	Lime (t/ha)					
		0.0			1.5		
		$MgSO_4$ (kg/ha)			$MgSO_4$ (kg/ha)		
		0.0	30.0	60.0	0.0	30.0	60.0
Soil pH (1:2.5)	5.0	4.8	5.0	4.9	5.5	5.4	5.6
Ca(cmol(+)kg^{-1})	3.0	3.1	3.2	2.9	4.5	4.3	4.6
Mg(cmol(+)kg^{-1})	1.4	1.2	2.3	2.6	1.1	2.1	2.5
K(cmol(+)kg^{-1})	0.20	0.17	0.21	0.18	0.21	0.20	0.16
Avail.P ($mgKg^{-1}$)	4.3	2.5	3.6	3.2	5.2	5.5	5.3
Org.M (gkg^{-1})	19.5	21.0	22.1	23.4	19.3	21.3	20.2

4.2 Effects of magnesium and calcium on growth of pectomech and tropimech

4.2.1 Effect of Variety and Magnesium on Plant Population (Retention) Regarding the interaction between different rates at which Magnesium was applied and the two varieties of tomato, significant differences were observed in plant population ($p \leq 0.05$) (Table 4.2). Plant population of pectomech to which 30 kg/ha of Magnesium was applied was significantly the highest (50116 plants/ha) while plant population of tropimech to which 60kg/ha of Magnesium was applied was significantly the least (38426 plants/ha).

For the individual effects, there were no significant differences ($p \geq 0.05$) among the different rates at which magnesium was applied. However, significant differences

($p \leq 0.05$) were observed between the two varieties, Pectomech and Tropimech. Pectomech was significantly higher (48997 plants/ha) in retention of plant population than Tropimech (42593 plants/ha).

Table 4.2: Effect of variety*magnesium on Plant population

Variety	Magnesium			Mean
	0t/ha	30kg/ha	60kg/ha	
Pectomech	48958[ab]	50116[a]	47917[ab]	48997[a]
Tropimech	44329[ab]	45023[ab]	38426[b]	42593[b]
Mean	46644[a]	47570[a]	43171[a]	

*Figures on the same column followed by the same letter are not significantly different

4.2.2 Effect of Variety and Calcium on Plant Population (Retention)

For effect of interaction between Calcium/Lime applied and variety on plant population, plant population of Pectomech to which 1.5t/ha of Calcium/Lime was applied (53935plants/ha) was significantly the highest while Tropimech to which no lime was applied had the least (41281plants/ha).

Individually, Pectomech variety (48997plants/ha) was statistically higher ($p \leq 0.05$) in plant population than Tropimech (42593 plants/ha). Calcium/ Lime rate at 1.5t/ha (48920plants/ha) was also significantly higher ($p \leq 0.05$) in plant population than calcium/Lime rate at 0t/ha (42670plants/ha) (Table 4.3).

Table 4.3: Effect of variety*calciumon Plant population

Variety	Calcium		Mean
	0t/ha	1.5t/ha	

Pectomech	44059^{b}	53935^{a}	48997^{a}
Tropimech	41281^{b}	43904^{b}	42593^{b}
Mean	42670^{b}	48920^{a}	

*Figures on the same column followed by the same letter are not significantly different

4.2.3 Effect of Variety and Lime on Leaf Area

From table 4.4, Tropimech variety to which 1.5t/ha of lime was applied was significantly higher ($p \leq 0.05$) in leaf area than Pectomech to which the same rate of lime was applied. However, the leaf area of Pectomech and Tropimech were similar at 0t/ha. For effect of the different rates at which calcium was applied on the leaf area, no significant difference ($p \geq 0.05$) was observed. However, significant difference ($p \leq 0.05$) was observed between the two varieties of tomato. Tropimech variety (16.12) was significantly higher in leaf area than Pectomech (12.43).

Table 4.4: VARIETY*LIME for leaf Area

Variety	Calcium		Mean
	0t/ha	1.5t/ha	
Pectomech	12.50^{bc}	12.36^{c}	12.43^{b}
Tropimech	16.02^{ab}	16.21^{a}	16.12^{a}
Mean	14.26^{a}	14.29^{a}	

*Figures on the same column followed by the same letter are not significantly different

4.2.4 Effect of Variety and Magnesium on Leaf Area

Interactively (Table 4.5), leaf area of Tropimech to which 30kg/ha of magnesium (17.49) was applied was significantly higher ($p \leq 0.05$) than leaf area of Pectomech to which no magnesium (12.19) and 60kg/ha Magnesium (11.97) was applied. However, the leaf area of Tropimech at the three different rates (0kg/ha, 30kg/ha and 60kg/ha) at which magnesium was applied were similar ($p \geq 0.05$) as well as leaf area of the Pectomech variety at the same rates of application.

Individually, statistical differences ($p \leq 0.05$) were observed between the varieties. Tropimech was statistically higher (16.12) in leaf area while Pectomech variety was statistically low (12.43). Statistical difference was also not observed ($p \geq 0.05$) among the three rates at which magnesium was applied. However, marginally, magnesium applied at 30kg/ha (15.31) was higher in leaf area, followed by magnesium applied at 0kg/ha (13.85) with magnesium applied at 60kg/ha (13.65) recording the least leaf area.

Table 4.5: Variety *Magnesium for Leaf Area

Variety	Magnesium			Mean
	0t/ha	30kg/ha	60kg/ha	
Pectomech	12.19[b]	13.13[ab]	11.97[b]	12.43[b]
Tropimech	15.52[ab]	17.49[a]	15.34[ab]	16.12[a]
Mean	13.85[a]	15.31[a]	13.65[a]	

*Figures on the same column followed by the same letter are not significantly different

4.2.5 Effect of Lime and Variety on Dropped Flowers

From Table 4.6, dropped flowers of Pectomech to which no calcium was applied was significantly higher ($p \leq 0.05$) than dropped flowers of Tropimech to which 1.5t/ha of Calcium (702894) was applied. The dropped flowers of Pectomech at 0t/ha and 1.5t/ha as well as Tropimech were similar

Individually, there was no significant difference ($p \geq 0.05$) between the varieties. However, the different rate at which calcium was applied showed significant differences ($p \leq 0.05$). No calcium applied significantly caused higher drop in flowers compared to calcium applied at 1.5t/ha which was significantly lower (791898). Effect of Magnesium/Calcium and variety on dry matter stalk weight, days to 50% flowering, plant height, canopy spread, branching and stem diameter showed no significant differences ($p \geq 0.05$). There was also no significant difference ($p \geq 0.05$) for effect of Magnesium and Variety on dropped flowers.

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Table 4.6 Dropped Flowers for Lime*Variety

Variety	Calcium		Mean
	0t/ha	1.5t/ha	
Pectomech	1.08E+06^{a}	880903^{ab}	979514^{a}
Tropimech	967361^{ab}	702894^{b}	835127^{a}
Mean	1.02E+06^{a}	791898^{b}	

*Figures on the same column followed by the same letter are not significantly different

4.3 Effects of magnesium and calcium on yield of pectomech and tropimech

4.3.1 Effect of Variety and Lime on Total Number of Tomato Fruits

Table 4.7 showed that the total fruit number of Pectomech (98032) to which no lime was applied was significantly higher ($p \leq 0.05$) than tropimech (39236) to which no lime was applied. The total number of fruit to which 1.5t/ha of lime was applied were similar for both Pectomech and Tropimech.

There was also no significant difference ($p \geq 0.05$) between the two different rates at which calcium was applied but significant difference ($p \leq 0.05$) was observed between the two varieties of tomato. Pectomech (93113) recorded significantly higher total number of fruits while that from Tropimech (57407) was significantly lower.

Table 4. 7 Total Fruit Number for VARIETY*LIME

Variety	Calcium		Mean
	0t/ha	1.5t/ha	

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Pectomech	98032[a]	88194[a]	93113[a]
Tropimech	39236[b]	75579[ab]	57407[b]
Mean	68634[a]	81887[a]	

*Figures on the same column followed by the same letter are not significantly different.

4.3.2 Effect of Variety and Calcium on Total Weight of Tomato Fruits Total fruit weight of Pectomech (2857.6) to which no lime was applied was significantly higher ($p \leq 0.05$) than tropimech (1091.2) to which no lime was applied. The total fruit weight of Pectomech and Tropimech at 1.5t/ha of calcium were similar as shown in Table 4.8 With respect to their individual effects, there was no significant difference ($p \geq 0.05$) between the two rates at which calcium was applied but significant difference ($p \leq 0.05$) was observed between the two varieties of tomatoes. Pectomech (2784.3) was significantly higher in total fruit weight than Tropimech (1675.7) which was lower. There was no significant effect of Magnesium and Calcium on yield weight, fruit number, marketable fruit weight and number, non-marketable fruit weight and number and different harvest fruit weight and number at 5% significance for both Pectomech and Tropimech.

8 Total Fruit Weight for VARIETY*LIME

Variety	Calcium		Mean
	0t/ha	1.5t/ha	
Pectomech	2857.6[a]	2710.9[a]	2784.3[a]

Table 4. :

Tropimech	1091.2^{b}	2260.2^{ab}	1675.7^{b}
Mean	1974.4^{a}	2485.5^{a}	

*Figures on the same column followed by the same letter are not significantly different

4.4 Effects of magnesium and calcium on postharvest quality of pectomech and tropimech

4.4.1 Effect of Calcium and Variety at Full-Ripe Stage on Total Titratable Acidity (TTA)

As far as the interaction was concerned (Table 4.9), there were significant differences ($p \leq 0.05$). Pectomech to which no calcium was applied was significantly the highest (10.31) in TTA while Tropimech to which 1.5t/ha of calcium was applied was the least (8.85). The TTA of both full ripe Pectomech and Tropimech at which no lime and 1.5t/ha of lime was applied were similar.

Although, the different rates at which lime was applied showed no significant difference ($p \geq 0.05$), there was significant difference ($p \leq 0.05$) between the varieties. The TTA of full ripe Pectomech (9.65) was significantly higher than Tropimech (8.88).

Table 4.

9: TTA level of Full Ripe Variety*Lime

Variety	Calcium		Mean
	0t/ha	1.5t/ha	
Pectomech	10.31[a]	8.99[ab]	9.65[a]
Tropimech	8.91[ab]	8.85[b]	8.88[b]
Mean	9.61[a]	8.92[a]	

*Figures on the same column followed by the same letter are not significantly different

4.4.2 Effect of Magnesium and Variety at Full-Ripe Stage on Total Titratable Acidity (TTA)

The results (Table 4.10) showed that TTA of full ripe Pectomech to which 60kg/ha of Magnesium was applied (9.86) was significantly higher ($p \leq 0.05$) than Tropimech to which 30kg/ha of Magnesium was applied (7.82). The TTA of Tropimech to which no calcium was applied (9.80) was significantly higher ($p \leq 0.05$) than that to which 30kg/ha of lime was applied (7.82) but similar to that at which 60kg/ha of Lime was applied (9.02).

TTA was not significantly ($p \geq 0.05$) affected by the different rates at which magnesium was applied. However, significant difference ($p \leq 0.05$) was observed between the varieties with Pectomech (9.65) recording the highest level of TTA while Tropimech (8.88) recorded the least.

10: TTA level of Full Ripe Variety*Magnesium

Table 4.

Variety	Magnesium			Mean
	0t/ha	30kg/ha	60kg/ha	
Pectomech	9.61[ab]	9.48[ab]	9.86[a]	9.65[a]
Tropimech	9.80[a]	7.82[b]	9.02[ab]	8.88[b]
Mean	9.70[a]	8.65[a]	9.44[a]	

*Figures on the same column followed by the same letter are not significantly different

4.4.3 Effect of Calcium and Variety at Breaker Stage on Total Soluble Solids (TSS)

From Table 4.11 Tropimech at breaker stage to which 1.5t/ha of lime was applied (4.97) significantly had the highest level of TSS. Pectomech at breaker stage to which no calcium (4.01) and 1.5t/ha of calcium (4.16) as well as tropimech to which 1.5t/ha of calcium was applied (4.21) were not significantly different ($p \geq 0.05$). However, the least TSS was recorded by Pectomech to which no lime was applied (4.01).

Individually, there was significant difference ($p \leq 0.05$) between the two different rates at which calcium was applied and the two varieties. Tropimech (4.59) recorded the highest significant level of TSS while Pectomech had the least. Calcium applied at 1.5t/ha (4.56) also recorded the highest significant level of TSS while that applied at 0t/ha recorded the least (4.11).

11: TSS level of Breaker Variety*Lime

Table 4.

Variety	Calcium		Mean
	0t/ha	1.5t/ha	
Pectomech	4.01^{b}	4.16^{b}	4.09^{b}
Tropimech	4.21^{b}	4.97^{a}	4.59^{a}
Mean	4.11^{b}	4.56^{a}	

*Figures on the same column followed by the same letter are not significantly different

4.4.4 Effect of Magnesium and Variety at Breaker Stage on Total Soluble Solids (TSS)

Table 4.12 showed that TSS of Tropimech at breaker stage to which 30kg/ha of Magnesium was applied was statistically the highest (4.88) while Pectomech to which nomagnesium was applied recorded the least (4.03). There was no significant difference ($p \geq 0.05$) between Tropimech to which 0kg/ha, 30kg/ha and 60kg/ha was applied as well as Pectomech to which the same rates of calcium was applied.

Individually, significant differences ($p \leq 0.05$) were observed. Magnesium applied at 30kg/ha (4.52) was significantly higher in TSS as compared to magnesium applied at 60kg/ha (4.31). Tropimech (4.59) also, significantly, had higher TSS than Pectomech (4.09) which had the least.

Table 4.12: TSS level of Breaker Variety*Magnesium

Variety	Magnesium			Mean
	0t/ha	30kg/ha	60kg/ha	
Pectomech	4.03^{c}	4.16^{bc}	4.07^{c}	4.09^{b}
Tropimech	4.33^{bc}	4.88^{a}	4.55^{ab}	4.59^{a}
Mean	4.31^{ab}	4.52^{a}	4.31^{b}	

*Figures on the same column followed by the same letter are not significantly different

4.4.5 Effect of Calcium and Variety at Half-Ripe Stage on Total Soluble Solids (TSS)

Significant ($p \leq 0.05$) TSS was observed for the interaction between the different rates at which lime was applied and the two varieties of tomato. TSS of half-ripe Tropimech to which 1.5t/ha of lime was applied (4.58) was significantly higher while Pectomech to which 1.5t/ha of lime was applied (4.05) was significantly the least. However, the TSS of both Pectomech and Tropimech were similar when no lime was applied. There was also significant difference ($p \geq 0.05$) between the two varieties of tomato. Half-ripe Tropimech (4.38) had higher TSS levels than Pectomech (4.13). However, significant difference was not observed ($p \geq 0.05$) for the different rates at which calcium was applied (Table 4.13).

Table 4.13: TSS level of Half Ripe Variety*Lime

Variety	Calcium	Mean

	0t/ha	1.5t/ha	
Pectomech	4.20^{b}	4.05^{b}	4.13^{b}
Tropimech	4.19^{b}	4.58^{a}	4.38^{a}
Mean	4.19^{a}	4.31^{a}	

*Figures on the same column followed by the same letter are not significantly different

4.4.6 Effect of Magnesium and Variety at Half-Ripe Stage on Total Soluble Solids (TSS)

For the interaction between magnesium and the varieties, there were significant differences ($p \leq 0.05$). Half-ripe Tropimech to which 60kg/ha of Magnesium was applied (4.53) was statistically higher in TSS while Pectomech to which 60kg/ha of Magnesium was applied (4.08) recorded the least. However, both Pectomech and Tropimech to which no magnesium was applied were similar as well those to which 30kg/ha of magnesium was applied. There were no significant differences ($p \geq 0.05$) between the different rates at which magnesium was applied but significant difference ($p \leq 0.05$) was observed between the varieties. Tropimech (4.38) was significantly higher in TSS level than Pectomech (4.13) which had the least (Table 4.14).

Table 4.14: TSS level of Half Ripe Variety*Magnesium

Variety	Magnesium			Mean
	0kg/ha	30kg/ha	60kg/ha	
Pectomech	4.18^{ab}	4.11^{b}	4.08^{b}	4.13^{b}

Tropimech	4.18[ab]	4.43[ab]	4.53[a]	4.38[a]
Mean	4.18[a]	4.27[a]	4.31[a]	

*Figures on the same column followed by the same letter are not significantly different

4.4.7 Effect of Calcium and Variety atFull-Ripe Stage on Total Soluble Solids (TSS)

From the results, TSS of full-ripe Tropimech to which 1.5t/ha of Lime was applied was significantly higher (p≥ 0.05) while Pectomech to which 1.5t/ha of lime was appliedrecorded the least.However, the TSS of both Pectomech and Tropimech were similar when no lime was applied. For the individual effects, full-ripe Tropimech (4.35) had a higher level of TSS compared to Pectomech (3.86) which recorded the least. There was no significant difference (p≥ 0.05) between the rates at which calcium was applied (Table 4.15).

Table 4.15: TSS level of Full Ripe Variety*Lime

Variety	Calcium		Mean
	0t/ha	1.5t/ha	
Pectomech	3.92[ab]	3.79[b]	3.86[b]
Tropimech	4.22[ab]	4.48[a]	4.35[a]
Mean	4.07[a]	4.13[a]	

*Figures on the same column followed by the same letter are not significantly different

4.4.8 Effect of Magnesium and Variety atFull-Ripe Stage on Total Soluble Solids (TSS)

The results showed full-ripe Tropimech to which nomagnesium was applied (4.80) to be the highest in TSS while Pectomech to which no magnesium was applied (3.69) had the least. There were, however, no significant differences ($p \geq 0.05$) between Pectomech and Tropimech to which 30kg/ha of magnesium was applied as well as those to which 60kg/ha of calcium was also applied. Individually, full-ripe Tropimech (4.35) had a higher level of TSS compared to Pectomech (3.86) which recorded the least. There was no significant difference ($p \geq 0.05$) between the rates at which magnesium was applied (Table 4.16).

Table 4.16: TSS level of Full Ripe Variety*Magnesium

Variety	Magnesium			Mean
	0kg/ha	30kg/ha	60kg/ha	
Pectomech	3.69^{b}	3.81^{b}	4.06^{ab}	3.86^{b}
Tropimech	4.80^{a}	4.02^{ab}	4.23^{ab}	4.35^{a}
Mean	4.25^{a}	3.91^{a}	4.15^{a}	

*Figures on the same column followed by the same letter are not significantly different

4.4.9 Effect of Magnesium and Variety at Breaker Stage on Dry Matter Content

For dry matter content, significant differences ($p \leq 0.05$) were observed for the interaction between the different application rates of magnesium and varieties. Pectomech to which no magnesium was applied (2.20) was significantly higher while the least was recorded for Pectomech to which60kg/ha of Magnesium was applied (0.56). There was no significant difference ($p \geq 0.05$) between the individual effects (Table 4.17).

Table 4.17: Dry Matter Content of Tomato Varieties/Breaker forn

(Variety*Magnesium)

Variety	Level of Magnesium			Mean
	0kg/ha	30kg/ha	60kg/ha	
Pectomech	2.20[a]	1.20[ab]	0.56[b]	1.32[a]
Tropimech	1.02[ab]	1.13[ab]	1.23[ab]	1.12[a]
Mean	1.61[a]	1.16[a]	0.90[a]	

*Figures on the same column followed by the same letter are not significantly different

4.4.10 Effect of Calcium and Variety at Breaker Stage on Firmness

From Table 4.18, firmness of Pectomech at the breaker stage to which no calcium was applied (5.43) was significantly higherwhile Pectomech to which 1.5t/ha of Calcium was applied (4.26) recorded the least.The firmness of Tropimech at 1.5t/ha and 0t/ha were similar.

For the individual effects on firmness, both the different rates at which calcium was applied and the two varieties showed significant differences ($p \leq 0.05$). Pectomech (4.84) at the breaker stage was significantly firmer than Tropimech (4.44). No calcium applied (4.86) recorded higher level of firmness than calcium applied at 1.5t/ha (4.42).

Table 4.18: Firmness of tomato varieties at breaker stage interacting with Calcium (Variety*Lime)

Variety	Calcium		Mean
	0t/ha	1.5t/ha	
Pectomech	5.43[a]	4.26[b]	4.84[a]
Tropimech	4.29[b]	4.59[b]	4.44[b]

Mean	4.86^{a}	4.42^{b}

*Figures on the same column followed by the same letter are not significantly different

4.4.11 Effect of Magnesium and Variety at Breaker Stage on Firmness

Table 4.19 showed that Pectomech to which 30kg/ha of Magnesium was applied (5.30) was significantly higher in firmness while Tropimech to which30kg/ha of Magnesium was applied (4.27) recorded the least.The Firmness of 0kg/ha as well as 60kg/ha was significantly similar for both varieties of Pectomech and Tropimech. There was no significant difference ($p \geq 0.05$) between the different rates at which magnesium was applied. However, Pectomech (4.84) was significantly firmer than Tropimech (4.44) for the individual effects.

Table 4.19: Firmness of tomato varieties interacting with Magnesium Breaker (Variety*Magnesium)

Variety	Magnesium			Mean
	0kg/ha	30kg/ha	60kg/ha	
Pectomech	4.42^{ab}	5.30^{a}	4.82^{ab}	4.84^{a}
Tropimech	4.37^{ab}	4.27^{b}	4.69^{ab}	4.44^{b}
Mean	4.39^{a}	4.79^{a}	4.75^{a}	

*Figures on the same column followed by the same letter are not significantly different

4.4.12 Effect of Calcium and Variety at Half-Ripe Stage on Firmness

The results (Table 4.20) showed that half-ripe Pectomech to which 1.5t/ha of lime was applied (3.79) recorded significantly the highest level of firmness whileTropimech to which no lime was applied (3.24) recorded the least. The firmness of both Pectomech and Tropimech to which no lime was applied was similar to Tropimech as well as those to which 1.5t/ha of Lime was applied.

The varieties recorded no significant differences ($p \geq 0.05$) for the individual effects. However, calcium applied at 1.5t/ha (3.63) was significantly firmer than calcium applied at 0t/ha (3.38).

Table 4.20: Firmness of half-ripe tomato varieties interacting with Calcium (Variety*Lime)

Variety	Calcium		Mean
	0t/ha	1.5t/ha	
Pectomech	3.47[ab]	3.79[a]	3.63[a]
Tropimech	3.24[b]	3.52[ab]	3.38[a]
Mean	3.36[b]	3.66[a]	

*Figures on the same column followed by the same letter are not significantly different

4.4.13 Effect of Magnesium and Variety at Half-Ripe Stage on Firmness For the interaction (Table 4.21), there were significant differences ($p \leq 0.05$) between the half-ripe varieties and magnesium. Half-ripe Pectomech to which no magnesium was applied (4.06) was significantly higher in firmness while Tropimech to which 60kg/ha of magnesium was applied (2.92) was significantly the least.

For the individual effects (Table 4.21), there was no significant difference ($p \geq 0.05$) in firmness for the varieties. However, magnesium applied at 60kg/ha (3.16) was significantly hardier than magnesium applied at 0kg/ha (3.82) and that applied at 30kg/ha (3.54).

Table 4. 21: Firmness of half-ripe tomato varieties interacting with Magnesium (Variety*Magnesium)

Variety	Magnesium			Mean
	0kg/ha	30kg/ha	60kg/ha	
Pectomech	4.06^{a}	3.43^{abc}	3.40^{bc}	3.63^{a}
Tropimech	3.58^{ab}	3.64^{ab}	2.92^{c}	3.63^{a}
Mean	3.82^{a}	3.54^{a}	3.16^{b}	

*Figures on the same column followed by the same letter are not significantly different

4.4.14 Effect of Calcium and Variety at Full-Ripe Stage on Firmness

Table 4.22 showed that firmness of full-ripe Pectomech at no lime (2.70) was significantly higher ($p \leq 0.05$) while Tropimech to which no lime was applied (1.98) recorded the least.However, both Pectomech and Tropimech to which 1.5t/ha of lime was applied were similar in respect to firmness.

Individually, there was no significant difference ($p \geq 0.05$) between the two different rates at which calcium was applied. However, Pectomech (2.44) was significantly firmer than Tropimech (2.22).

Table 4.22: Firmness of full Ripe tomato varieties interacting with calcium (Variety*Lime)

Variety	Calcium		Mean
	0t/ha	1.5t/ha	

Pectomech	2.70[a]	2.18[bc]	2.44[a]
Tropimech	1.98[c]	2.46[ab]	2.22[b]
Mean	2.34[a]	2.32[a]	

*Figures on the same column followed by the same letter are not significantly different

4.4.15 Effect of Magnesium and Variety at Full-Ripe Stage on Firmness From Table 4.23, firmness of full-ripe Pectomech to which no magnesium was applied (2.85) was significantly the highest. Pectomech to which 30kg/ha and 60kg/ha of Magnesium was applied as well as Tropimech to which 0kg/ha, 30kg/ha and 60kg/ha was applied showed no significant differences (p≥ 0.05). However, marginally the least firmness was recorded by pectomech to which 60kg/ha of magnesium was applied (2.14) Regarding the individual effects, Pectomech (2.44) recorded the highest firmness level while Tropimech (2.22) recorded the least. For the magnesium levels applied, no application of magnesium (2.59) was significantly higher in firmness than magnesium at both 30kg/ha (2.25) and 60kg/ha (2.15).

Table 4.23: Firmness of full Ripe tomato varieties interacting with calcium (Variety*Magnesium)

Variety	Magnesium			Mean
	0kg/ha	30kg/ha	60kg/ha	
Pectomech	2.85[a]	2.33[b]	2.14[b]	2.44[a]
Tropimech	2.32[b]	2.17[b]	2.16[b]	2.22[b]
Mean	2.59[a]	2.25[b]	2.15[b]	

*Figures on the same column followed by the same letter are not significantly different

4.4.16 Effect of Calcium and Variety at Red-Ripe Stage on Firmness

From Table 4.24, there was significant firmness between the varieties at red-ripe stage and the different rates at which calcium was applied. Red-ripe Pectomech to which no lime was applied (2.84) was significantly firmer while Tropimech to which 30kg/ha of Lime was applied (2.84) was significantly the least.However, Pectomech to whichno lime wasapplied (1.10) was similar in firmness to Tropimech to which 1.5t/ha was applied (1.88). The least firmness was recorded by Pectomech to which no lime was applied.

For the individual effect, there was no significant difference (p≥ 0.05) between the varieties. However, there was significance difference (p≤ 0.05) between the rates at which calcium was applied. No application of calcium (2.42) yielded firmer fruits than those to which 1.5t/ha of calcium was applied (2.22).

Table 4.24: Firmness of Red Ripe tomato varieties interacting with calcium (Variety*Lime)

Variety	Calcium		Mean
	0t/ha	1.5t/ha	
Pectomech	1.10[c]	2.56[b]	2.28[a]
Tropimech	2.84[a]	1.88[c]	2.36[a]
Mean	2.42[a]	2.22[b]	

*Figures on the same column followed by the same letter are not significantly different

4.4.17 Effect of Magnesium and Variety at Breaker Stage on Moisture Content

For moisture content, there was significant interaction difference ($p \leq 0.05$) between the different rates at which magnesium was applied and the varieties. Moisture content of Pectomech at breaker stage to which no magnesium was applied (62.33) was significantly the highest while Pectomech to which 60kg/ha of magnesium was applied (32.29) had the least. The moisture content of Pectomechat 0kg/ha, 30kg/ha and 60kg/ha was significantly similar as well as Tropimech at the same levels. However, the individual effects showed no significant differences ($p \geq 0.05$) in terms of moisture content (Table 4.25).

Table 4.

25: Moisture Content of tomato varieties at Breaker stage

(Variety*Magnesium)

Variety	Magnesium			Mean
	0kg/ha	30kg/ha	60kg/ha	
Pectomech	62.33^{a}	47.54^{ab}	32.29^{b}	47.38^{a}
Tropimech	47.35^{ab}	51.48^{ab}	52.20^{ab}	50.34^{a+}
Mean	54.88^{a}	49.51^{a}	42.24^{a}	

*Figures on the same column followed by the same letter are not significantly different

4.4.18 Effect of Magnesium and Variety at Full-Ripe Stage on Pericarp Thickness

Table 4.26 showed that there was significant interaction difference ($p \leq 0.05$) between the different rate at which magnesium was applied and varieties Pericarp thickness of full-ripe Pectomech to which 60kg/ha of magnesium was applied (5.67) was significantly the highest while Tropimech to which 30kg/ha of Magnesium was applied (4.53) was the least. Individually, the two varieties of tomato showed no significant difference ($p \geq 0.05$) in pericarp thickness. However, the pericarp thickness of magnesium at 60kg/ha (5.62) was significantly higher than that at both

0kg/ha (4.96) and 30kg/ha (4.86).

Table 4.26: Pericarp Thickness of Full Ripe tomato varieties (Variety*Magnesium)

Variety	Magnesium			Mean
	0kg/ha	30kg/ha	60kg/ha	
Pectomech	4.96[ab]	5.26[ab]	5.67[a]	5.30[a]
Tropimech	4.96[ab]	4.53[b]	5.57[ab]	5.02[a]
Mean	4.96[b]	4.89[b]	5.62[a]	

*Figures on the same column followed by the same letter are not significantly different

4.4.19 Effect of Calcium and Variety at Red-Ripe Stage on Pericarp Thickness

From Table 4.27, the pericarp thickness of red-ripe Pectomech to which 1.5t/ha of calcium was applied (5.65) was significantly the highestwhile Pectomech to which no calcium was applied (5.05) recorded the least. The firmness of Tropimech at 1.5t/ha and 0t/ha were significantlysimilar ($p \geq 0.05$).

Although, individually, the varieties showed no significant difference ($p \geq 0.05$), there was significant difference ($p \leq 0.05$) between the different rates at which calcium was applied. Calcium applied at 1.5t/ha (5.58) was significantly higher in pericarp thickness than that without calcium application (5.06).

27: Pericarp Thickness of tomato varieties of Red Ripe (Variety* Lime).

Variety	Calcium		Mean
	0t/ha	1.5t/ha	

Table 4.

Pectomech	5.05^{b}	5.65^{a}	5.35^{a}
Tropimech	5.06^{ab}	5.52^{ab}	5.29^{a}
Mean	5.06^{b}	5.58^{a}	

*Figures on the same column followed by the same letter are not significantly different

4.4.20 Effect of Calcium and Variety on Fruit Diameter

The results (Table 4.28) showed that fruit diameter of Pectomech to which1.5t/ha of lime was applied (40.60) was significantly the highest but similar to Pectomech to which nolime was applied as well as Tropimech to which both 0t/ha and 1.5t/ha was applied. However, Pectomech to which no lime was applied was significantly the least.

For the individual effects, there were significant differences ($p \leq 0.05$). The fruit diameter of Tropimech (40.36) was significantly bigger than Pectomech (37.99). Calcium to which 1.5t/ha was applied (40.04) had bigger fruit diameter thanthat which had no calcium application.

Table 4.

28: Fruit Diameter (mm) of tomato varieties (Variety *Lime).

Variety	Calcium		Mean
	0t/ha	1.5t/ha	
Pectomech	36.54^{b}	39.43^{a}	37.99^{b}
Tropimech	40.11^{a}	40.60^{a}	40.36^{a}
Mean	38.32^{b}	40.08^{a}	

*Figures on the same column followed by the same letter are not significantly different

4.4.21 Effect of Magnesium and Variety on Fruit Diameter

For the interaction effect (Table 4.29), fruit diameter of pectomech to which 60 kg/ha of magnesium was applied (41.07) was significantly the highest while the fruit diameter of Pectomech to which 30kg/ha Magnesium was applied (33.64) was significantly the least.

Regarding the individual effect, significant differences ($p \leq 0.05$) were observed. Tropimech (40.36) had significantly bigger fruit diameter while Pectomech (37.99) had the least. Magnesium applied at 60kg/ha (40.74) also had significantly higher fruit than magnesium applied at 30kg/ha (37.54) but it was not significantly different from that to which no magnesium was applied (39.53).

29: Fruit Diameter (mm) of tomato varieties (Variety *Magnesium)

Table 4.

Variety	Magnesium			Mean
	0kg/ha	30kg/ha	60kg/ha	
Pectomech	39.25[a]	33.64[b]	41.07[a]	37.99[b]
Tropimech	39.82[a]	40.83[a]	40.42[a]	40.36[a]
Mean	39.53[a]	37.24[b]	40.74[a]	

*Figures on the same column followed by the same letter are not significantly different

4.4.22 Effect of Calcium and Variety on Fruit Rot

From Table 4.30, there were significant differences ($p \leq 0.05$) among the interaction effects. Fruit rot of Pectomech to which 1.5t/ha of lime was applied (28.57) was significantly higher whereas Tropimech to which 1.5t/ha of lime was applied (9.52) was the least. However, the fruit rot of both Pectomech and Tropimech were similar when no lime was applied.

Individual effects showed that Pectomech varieties of tomato (23.02) significantly had the highest number of fruit rot while Tropimech (11.91) had the least. There were, however, no significant differences ($p \geq 0.05$) between the rates at which lime was applied.

Table 4. 30: Percent Fruit Rot of tomato varieties (Variety *Calcium)

Variety	Calcium		Mean
	0t/ha	1.5t/ha	
Pectomech	17.46[ab]	28.57[a]	23.02[a]
Tropimech	14.29[ab]	9.52[b]	11.91[b]
Mean	15.87[a]	19.05[a]	

*Figures on the same column followed by the same letter are not significantly different

4.4.23 Effect of Calcium and Variety on Shrivelled Fruit

Table 4.31 showed that fruit of Pectomech to which 1.5t/ha of lime was applied (5.27) was significantly shrivelledwhile Tropimech to which 1.5t/ha of lime was applied (2.62) had the least shrivelled fruit. However, the fruits of both Pectomech and Tropimech were similar when no lime was applied.

Individually, the different rates at which calcium was applied showed no significant difference ($p \leq 0.05$) with respect to shrivelled fruits. However, fruits of Pectomech varieties (4.55) were significantly shrivelled while tropimech (3.06) recorded least number of shrivelled fruits. There was no significance difference of Calcium and Magnesium on TTA (breaker, half-ripe, red-ripe stages), TSS (red ripe stage), firmness (red ripe stage-variety), moisture content (breaker/ half-ripe stagesvariety*lime), full-ripe, red-ripe stages, pericarp thickness (breaker, half-ripe, fullripe variety*lime, red ripe-variety*magnesium) among fruit rot, fruit shrink, dry matter weight of breaker, half-ripe, full-ripe and red-ripe stages at 5% significance.

Table 4. 31: Number of Shrivelled Fruits of tomato varieties (Variety* Lime)

Variety	Calcium		Mean
	0t/ha	1.5t/ha	
Pectomech	3.84[ab]	5.27[a]	4.55[a]
Tropimech	3.49[ab]	2.62[b]	3.06[b]
Mean	3.66[a]	3.95[a]	

*Figures on the same column followed by the same letter are not significantly different

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4.5 EDTA titrimetric analysis of calcium and magnesium absorption rate

4.5.1 Calcium Absorption Rate of Tomato Varieties

Table 4.32 showed the effects of liming and magnesium application on calcium absorption. It reveals that, in the absence of both lime and magnesium, pectomech absorbed higher calcium (0.80%) than tropimech (0.60%). When magnesium was applied alone at various levels, there was also a lot more calcium absorbed by tropimech relative to pectomech (0.44 vs. 0.28 at 30 $MgSO_4$ and 0.80 vs 0.36. at 60 $MgSO_4$). However, when, lime was appliedalone, tropimech absorbed higher Ca than Pectomech (0.52 against 0.48). Again, after the application of lime and magnesium at various levels, tropimech absorbed higher Ca (0.96) relative to pectomech (0.12) at 30MgSo4 while at 60$MgSO_4$, tropimech absorbed higher (0.72) than pectomech (0. 48).

Table 4.32: Calcium absorption rate of tomato varieties (%)

Variety	Lime (t/ha)	Mean

	Lime 0.0			Lime 1.5			
	MgSO4 (kg/ha)			MgSO4 (kg/ha)			
	0.0	30.0	60.0	0.0	30.0	60.0	
Tropimech	0.60	0.44	0.80	0.52	0.96	0.72	0.67
Pectomech	0.80	0.28	0.36	0.48	0.12	0.48	0.42
Mean	0.70	0.36	0.58	0.50	0.54	0.60	

4.5.2 Magnesium Absorption Rate of Tomato Varieties

From Table 4.33, the effects of liming and magnesium application on magnesium absorption are shown. It revealed that, in the absence of both lime and magnesium, pectomech absorbed higher magnesium (0.43) than tropimech (0.19). When magnesium was applied alone at different levels, there was a lot more calcium absorbed by pectomech relative to tropimech (0.58 vs 0.41 at 30 $MgSO_4$ and0.50 vs0.29. at 60 $MgSO_4$). However, when lime was appliedalone, pectomech absorbed higher Ca than tropimech (0.50 against 0.36) while after the application of both lime and magnesium at various levels, pectomech absorbed higher Ca relative to pectomech.

Table 4.33: Magnesium absorption rate of tomato varieties (%).

Variety	Lime (t/ha)					
	0.0			1.5		
	MgSO4 (kg/ha)			MgSO4 (kg/ha)		
	0.0	30.0	60.0	0.0	30.0	60.0
Tropimech	0.19	0.41	0.29	0.36	0.31	0.24
Pectomech	0.43	0.58	0.50	0.50	0.72	0.29

CHAPTER 5

DISCUSSION OF FINDINGS

5.1 Soil Analysis

Soil analysis of the field indicated no effect on pH as a result of Magnesium application. There was, however, an effect when Magnesium and Calcium were applied together to the soil. Magnesium and Calcium application did not in any way affect Potassium content in the soil. However, Magnesium level increased when it was either applied alone or in combination with lime. Phosphorous levels also decreased in the process, whereas, organic matter increased after cropping.

Potassium was however not affected by either Magnesium or Calcium treatment. Lime applied at 1.5 t/ha resulted in an increased soil pH by at least 0.4 units. Lime applied at 1.5 t/ha also increased exchangeable Calcium by at least 1.2 cmol (+) kg^{-1} and available Phosphorus by at least 1.9 $mgkg^{-1}$. Application of $MgSO_4$ increased exchangeable Mg by 1.0 cmol (+) kg^{-1}. Changes in the other soil properties showed no particular trend.

This corroborates a report from Jones (1999) which stated that slight magnesium deficiency occurs in almost all crops grown in all soil types, but severe deficiencies can be expected on coarse-textured sandy soils. It is promoted by low pH and high potassium and status in the soil, and by inadequate supply in nitrogen fertilizers

5.2 Effects of Magnesium and Calcium on Growth and Development of Pectomech and Tropimech

Magnesium and Calcium at various levels had varying effects on plant population of Pectomech and Tropimech. The effects of the Calcium and Magnesium on plant population were higher in Pectomech and Tropimech for some levels, while in some instances, no effect on population was observed for the same magnesium treatment. The possible reason for the lower Magnesium and Calcium effect could be attributed to the fact that tomato plants were susceptible to diseases.

From the study, it was observed that Calcium increased and improved the leaf area of Tropimech. However, it was not in confirmation with findings of Hao and Papadopolous (2003) who concluded that high Calcium concentration does not affect leaf photosynthesis but rather reducedthe leaf area of Pectomech. Park *et al*. (2005) also reported that Calcium does not have deleterious effects on plant growth but rather has serious alterations on plant development and morphology. However, control of Calcium and Magnesium leads to ample growth and this was also at variance with the findings in this study. Differences could be as a result of change in environmental conditions, cultural practices and varieties of tomatoes.

Calcium had no significant effect on dropped flowers especially with respect to Pectomech and these findings, again, contradicted Al-Hamzawi (2010) report which revealed that Ca had superior effect on plant vegetative characters. This finding also contradicted Upadhyay and Patra (2011) as well as Ayyub *et al*. (2012) report which stated that both Magnesium and Calcium enhanced vegetative growth of plants.

Results from the study also showed that there was no significant effect of Calcium and Magnesium on dry matter stalk weight, days to 50% flowering, plant height, canopy spread, branching and stem diameter. Again, it contradicted with an experiment done by Chapagain and Wiesman (2003) and Olaniyi (2009) who reported that Magnesium and Calciumpromoted vegetative growth. These differences in results could again be attributed to changes in environmental condition, cultural practices and varieties of tomatoes.

Specifically effect of interaction between variety (Pectomech or Tropimech) and magnesium as far as dropped flowers was concerned showed significant relationship but could still not be established on growth as stated by Hao and Papadopoulos (2003) who concluded that it improved plant growth and had the best root systems. Again, Rab and Haq (2012) indicated quite clearly that the application of $CaCl_2$ alone significantly increased the plant height and it was confirmed by Ayyub *et al*. (2012) who reported that a significant improvement in growth of tomato fruit was observed with application of calcium chloride.

Upadhyay and Patra (2011) reported that the effect of calcium and magnesium was found to be higher in respect of growth parameters including plant height, number of branches per plant, width of flower and number fresh weight (g) of flower. A positive correlation between plant growth and application of calcium chloride was therefore not surprising.

5.2 Effects of Magnesium and Calcium on Yield of Pechtomech and Tropimech

Calcium had no effect on total fruit number of Pectomech and Tropimech and itwas at variance with the findings from Hoa and Papadopolous (2003) which showed that Calcium had significant effect on yield.Magnesium concentration, however, decreased fruit yield. Nzanza (2006) stated that Magnesium and Calcium decreased fruit size and dry matter yields and this was affirmed by findings from this study.

Nzanza (2006) contradicts that his findings by saying that Calcium improved tomato fruit yield and reduced the incidence of blossom-end rot (BER). Rab and Haq (2012) reported there was significant effect of Calcium on yield as it increased fruits per plant, fruits per cluster, fruits per plant, and fruit weight but this again was at variance with findings from this experiment. However, Chapagain and Wiesman (2003) reported that there was no significant effect of different treatments of Calcium/Magnesium on fruit yield as well as Johnstone (2008) and this was what was recorded in this experiment.

Tropimech recorded the highest yield as a result of Calcium application to the crop and this was consistent with findings of Rab and Haq (2012) who found that the application of Calcium alone significantly increased the fruit weight (96.33 g). This was also confirmed by Ayyub *et al*. (2012) who reported that the highest fruit weight was recorded as a result of Calcium treatment application.

There was no significant effect on yield weight and it was confirmed by

Papadopolous (2003) who was given us to understand stated that the fruit yield in the late growth stage decreased in significant terms. Magnesium and Calcium had no significant effect on marketable fruit yield which is in line with Nzanza (2006) who concluded that high Calcium and Magnesium ratios reduced marketable yield/weight and also in conformity with Johnstone (2008) who concluded that Calcium fertigation had no effect on marketable yield.

Calcium/Magnesium had no effect on fruit weight and Chapagain and Wiesman (2003) agrees to this. High Calcium concentration improved fruit yield. However, Calcium in combination with Magnesium had no significant effect on yield weight which again was in contradiction with Rab and Haq (2012) who in their investigations concluded that Calcium in combination with Magnesium does improves fruit weight and number.

Lack of significance of Calcium/Magnesium on yield was also disapproved by Ayyub *et al*. (2012) who confirmed significance of increase in fruit yield through highest fruit set, number of fruits per plant as well as fruit weight per plant.

All these differences could be easily attributed to weather and suspected late blight disease which attacked the crop towards the tail end of the fruiting process.

5.3 Magnesium and Calcium Effects on Postharvest Quality of Pechtomech and Tropimech

Quality attribute of full-ripe Tropimech (TTA) was not significantly affected by Calcium application which was similar to work of Nzanza (2006). He concluded after a trial work on tomato to determine nutrient and eating quality of the crop that Magnesium/Calcium decreased the Titrable Acidity of tomatoes. Awang et *al*. (2011) also upon investigation concluded that Calcium application did not in any way affect Titrable Acidity of tomatoes.

Ahmad and Mahdi (2012) however, disputed in their findings and concluded that Ca application had significant effect on TTA and maximum amount of fruit acidity was achieved when levels of Calcium treatment was controlled.

Magnesium treatment on full-ripe pectomech variety significantly affected TTA of Pectomech but contradicted Nzanza (2006) who reported that high Ca:Mg ratios (20:1) decreased tomato titratable acidity (TA) and Awang et *al*. (2011) also concluded that Magnesium treatment did not positively affect Titrable Acidity (TA) of tomato crop.

Magnesium and Calcium had significant effect on TSS of Tropimech at breaker, half-ripe and full-ripe stages of tomato variety. Interaction between Pectomech or Tropimech and either Calcium or Magnesium was found to be at variance with Hoa and Papadopolous (2003) who revealed through their investigations that Calcium reduces the TSS of tomato fruits. The research findings also contravenes the findings of Nzanza (2006) who upon lab trial realized that Calcium had no significant effect but rather further reduces Total Soluble Solids (TSS) of tomato fruits. Nonetheless, it was concluded that high potassium rates yielded higher fruit quality parameters such as PA, TSS and TA. Rab and Haq (2012) findings coincides with this research work and concludes that Ca application had significant effect on TSS content of tomato fruits.

However, Ahmad and Mahdi (2012) per the result of their investigation confirmed the findings of this piece of work by stating that Ca indeed had significant effect on TSS of tomato fruits.

When Magnesium was applied, Tropimech recorded the highest dry matter of breaker stage of tomato at 60kg/ha and the reverse was true for Pectomech when at this time round, the application level was 30kg/ha instead. From the analysis it was realized that the effect of Magnesium on dry matter alternates effects on both Tropimech and Pectomech at different Magnesium rates which also means that both varieties responsed differently at various levels with respect to Tropimech and Pectomech for Magnesium treatments.

From this we can logically conclude that Magnesium had lineal increasing effect for both Tropimech and Pectomech in which the findings contradicted Hao and Papadopoulos (2003) work which concluded that Magnesium did not affect early growth or fruit production. Magnesium concentration required for achieving high dry matter increased as the plant aged. Therefore, for better yield of quality Magnesium or Calcium may be recommended for tomato crop.

The highest total antioxidant activity was observed in the treatment with a high proportion of Magnesium which relatively affected dry matter in the end just as a high proportion of Calcium reduced the incidence of blossom-end rot (BER) and bothers the dry matter as indirectly reported by Fanasca (2012). Dry matter production was affected by field capacity and the uptake of Calcium and Magnesium was significantly affected by water stress which increased sugar and acid contents thereby reducing quality (Nahar and Gretzmacher, 2002).

From the results of this work it came to light that, fruit firmness had no significant effect on breaker through to red ripe stages of Pectomech and Tropimech when it interacted with lime or magnesium. Varieties not treated with Magnesium or Calcium had the firmest fruits than those applied with different levels of Magnesium and Calcium levels and it was in conformity with Hao and Papadopoulos (2003) who found that high Ca concentration reduced fruit.

Johnstel (2008) however, disagreed in his work and concluded that Calcium concentration did not affect fruit firmness. The findings of this work also vehemently were disputed by Ahmad and Mahdi (2012) who among others concluded that Calcium in application to fruits had significant effect on fruit firmness.

On the other hand when Pectomech or Tropimech interacted with Magnesium regarding firmness, it was observed that Magnesium as well as Calcium had significant effect on fruit firmness. By this it was also realized that the findings were not in line with that of Hao and Papadopoulos (2003) who upon investigation to find the effect of Ca/Mg on quality parameters realized that high Calcium application reduced fruit firmness and fruit firmness rather increased with increasing Mg levels.Rab and Haq (2012) investigations coincided with this research findings where conclusion was made that Calcium application resulted in fruit firmness.

However, this work was confirmed by Awang et *al*. (2011) study which stated that fruit firmness was enhanced by Ca treatment in application. This work was also in line with Chapagain and Wiesman (2003) reported which stated that Ca/Mg application improves fruit firmness.

Magnesium application had negative correlation on moisture content of the tomato fruits. Although no application of magnesium recorded the highest moisture level, magnesium applied at different rates produced similar moisture level for both varieties of Tropimech and Pectomech.

Magnesium and Calcium had significant effect on pericarp thickness with regard to Pectomech and Tropimech at different ripe stages. No application of Magnesium produced the fruits with thicker pericarp. Whereas Magnesium application at different rates yielded crops with the least pericarp thickness as well as Calcium applied also at different.

Fruit Diameter of Tropimech became bigger when Calcium was applied at different rates. Tropimech to which no calcium was applied yielded similarly bigger fruit diameter. Pectomech applied with different rates of Magnesium pectomech also recorded higher fruit diameter. However, there was no significance for the varieties which were not treated with magnesium. Although, calcium and magnesium had significant effect on diameter of tomato fruits, calcium had negative effect on fruit rot for both Tropimech and Pectomech.

5.4 Calcium

The calcium in fruits were significantly affected by increase of calcium levels in nutrients and it was affirmed by Paiva *et al* (1998b) who found that Calcium levels in tomato fruit increased with increasing Calcium levels reaching a maximum value of 0.72% and 0.48% of calcium concentration. Furthermore it is also inline with Taylor (2008) report which stated that Calcuim had significant effect on fruit concentration of Calcium afterharvest. Awang *et al*. (2011) also agreed by concluding that calcium application as postharvest treatment markedly elevated fruit Calcium content in the peel.

5.5 Magnesium

There was significant evidence that Calcium rates affected Magnesium content of tomato fruits (Table 4.26). This coincided with Olaniyi (2009) findings which stated that Magnesiumled to significant but higher levels of Mg content and that Magnesium application improved fruit quality of tomato. Hao and Papadopoulos (2000) also concluded at the end of their study that Magnesium had the best root systems and therefore for both yield and quality tomato fruits Magnesium may be recommended.

According to Paiva *et al* (1998b), Magnesium levels into tomato fruit decreased linearly with increasing Calcium in the nutrient medium. From the experiment, Ca: Mg ratio indeed increased Magnesium and Calcium levels did not aggravate the Magnesium absorption rate and efficiency. Thus, it could be concluded that the lower levels or no Mg/Ca rate was insufficient to increase Magnesium absorption rate. There was also a significant interaction between the Ca/Mg levels. This could be because of the antagonistic behaviour between Magnesium, Calcium and potassium.

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CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The aim of this study was to investigate the effects of calcium and magnesium on growth, yield and postharvest quality of two popular varieties of tomato. Tomato has contributed immensely to the *per capita* Gross Domestic Product (GDP) and export earnings of many countries worldwide including China. Tomato is crucial in our economy asa means of livelihood for the rural poor by providing employment for the rural folk and peri-urban areas of our society and also a very challenging way of reducing our foreign exchange earnings on its importation and more importantly, its extensive use in our diet in several diverse way especially in our modern day Ghanaian dishes. Tomatoes are vital to human nutrition, supplying folate, vitamin C, potassium, and more importantly, carotenoids (vitamin A precursors with strong antioxidant activity), the most important of which are; lycopene and beta-carotene which protect the cells of the body from oxidative damage in that lycopene together with other carotenoids such as phytoene and phytofluene are effective in preventing the proliferation of cancer cells.

Thus, first, we investigated to identify the effects of Ca and Mg on growth of two popular varieties of tomatoes (tropimech and pectomech). The results categorically revealed that both Calcium and Magnesium had significant effects on plant population and someof the parameters of growth including plant leaf area and dropped flowers.

Furthermore, the results showed that the effects of Calcium and Magnesium on yield of both pectomech and tropimech had significant effects on yield (total fruit weight and number).

Finally, on the effects of Calcium and Magnesium on postharvest quality of pectomech and tropimech, we found that, both varieties responded significantly as far as postharvest quality parameters such as dry matter weight and content, TSS, TTA, firmness, moisture content, pericap thickness, fruit diameter, rot, shrivel and magnesium absorption rate were concerned. Interestingly for moisture content, it was found that while pectomech responded positively to Ca/Mg the reverse was true for tropimech, whereas, also in Calcium absorption the response to Ca/Mg was vice versa in terms of moisture content.

6.2 Recommendations

Other studies on tomato are possible. Research can be done to look at the effects of other macro nutrients such as Phosphorous, Potassium etc on growth, yield and postharvest quality of tomatoes. Multi-locational trial should be conducted as well on the above mentioned parameters. Further studies can also be conducted on other varieties such as tomato mongal, wosowoso and other hybrid seed varieties.

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APPENDICES

Appendix 1

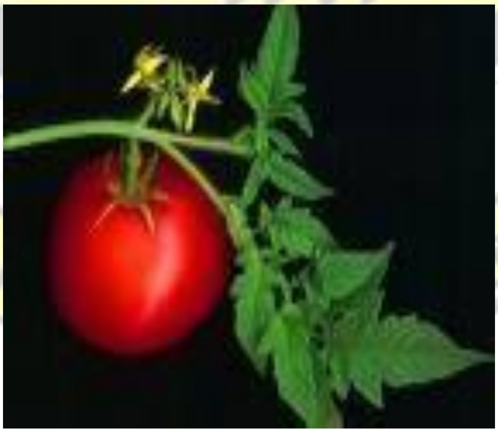

Plate: 1 Leaf of tomato with leaflets and fruit

Plate: 2Tomato flower

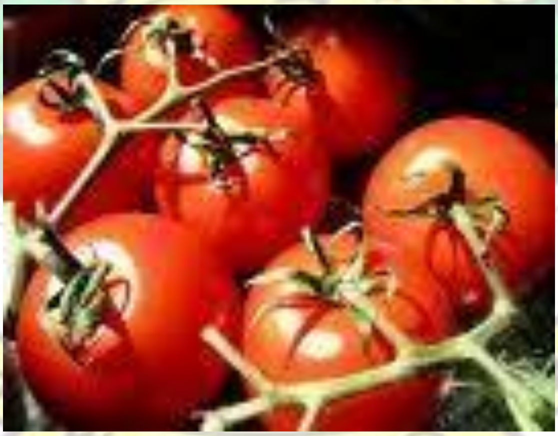

Plate: 3 Mature red ripe tomato fruit

Plate: 4 Immature green tomato fruits

Appendix 2

TTA

Analysis of Variance Table for Breaker

Source DF SS MS F P REP

2 7.09542 3.54771 variety 1 6.944E-05

0.00007 0.00 0.9962 Ca 1 0.00174

0.00174 0.00 0.9812 Mg 2 9.40792

4.70396 1.54 0.2374 variety*Ca 1 1.34174

1.34174 0.44 0.5148 variety*Mg 2 3.76681

1.88340 0.62 0.5496 Ca*Mg 2 9.48514

4.74257 1.55 0.2347 variety*Ca*Mg 2 4.63847

2.31924 0.76 0.4807

Error 22 67.3546 3.06157

Total 35 103.092

Grand Mean 9.4708 CV 18.47

Analysis of Variance Table for Halfripe

Source DF SS MS F P REP

2 1.148 0.57424 variety 1 2.054

2.05444 0.39 0.5387 Ca 1 0.111

0.11111 0.02 0.8859 Mg 2 3.197

1.59840 0.30 0.7413 variety*Ca 1 0.514

0.51361 0.10 0.7578 variety*Mg 2 14.223

7.11174 1.35 0.2799 Ca*Mg 2 15.755

7.87757 1.50 0.2461 variety*Ca*Mg 2 0.568

0.28424 0.05 0.9476 Error 22 115.893

5.26787

Total 35 153.465

Grand Mean 9.8528 CV 23.29

Analysis of Variance Table for Fullripe

Source DF SS MS F P REP

2 5.3772 2.68861 variety 1 5.3669

5.36694 4.59 0.0434 Ca 1 4.2025

4.20250 3.60 0.0711 Mg 2 7.2101

3.60507 3.09 0.0659 variety*Ca 1 3.5469

3.54694 3.04 0.0954 variety*Mg 2 5.2018

2.60090 2.23 0.1317 Ca*Mg 2 1.7879

0.89396 0.77 0.4772 variety*Ca*Mg 2 11.9235

5.96174 5.10 0.0151

Error 22 25.7011 1.16823

Total 35 70.3181

Grand Mean 9.2639 CV 11.67

Analysis of Variance Table for Redripe

Source DF SS MS F P REP

2 4.587 2.2933 variety 1 0.360 0.3600

0.12 0.7310 Ca 1 4.134 4.1344 1.39

0.2507 Mg 2 1.713 0.8565 0.29 0.7523

variety*Ca 1 1.647 1.6469 0.55 0.4644

variety*Mg 2 29.186 14.5931 4.91 0.0172

Ca*Mg 2 8.941 4.4705 1.51 0.2440

variety*Ca*Mg 2 12.941 6.4705 2.18 0.1370

Error 22 65.348 2.9704

Total 35 128.857

Grand Mean 8.7417 CV 19.72

TSS

Analysis of Variance Table for Breaker

Source DF SS MS F P REP

2 0.12451 0.06225 variety 1 2.25000

2.25000 45.34 0.0000 Ca 1 1.86778

1.86778 37.64 0.0000 Mg 2 0.72395

0.36198 7.29 0.0037 variety*Ca 1 0.83012

0.83012 16.73 0.0005 variety*Mg 2 0.26963

0.13481 2.72 0.0882 Ca*Mg 2 0.73556

0.36778 7.41 0.0035 variety*Ca*Mg 2 0.28617

0.14309 2.88 0.0773

Error 22 1.09179 0.04963

Total 35 8.17951

Grand Mean 4.3370 CV 5.14

Analysis of Variance Table for Halfripe

Source DF SS MS F P

REP 2 0.12117 0.06059
variety 1 0.58778 0.58778 10.91 0.0032 Ca

1 0.13444 0.13444 2.49 0.1285 Mg 2

0.10414 0.05207 0.97 0.3961 variety*Ca 1

0.65790 0.65790 12.21 0.0021 variety*Mg 2

0.33130 0.16565 3.07 0.0665 Ca*Mg 2

0.34463 0.17231 3.20 0.0604 variety*Ca*Mg 2

0.21377 0.10688 1.98 0.1614

Error 22 1.18549 0.05389

Total 35 3.68062

Grand Mean 4.2537 CV 5.46

Analysis of Variance Table for Fullripe

Source DF SS MS F P REP

2 0.5646 0.28231 variety 1 2.2003

2.20028 8.88 0.0069 Ca 1 0.0336

0.03361   0.14   0.7162 Mg   2   0.7022

0.35111   1.42   0.2639 variety*Ca   1   0.3667

0.36670   1.48   0.2368 variety*Mg   2   1.6822

0.84111   3.39   0.0520 Ca*Mg   2   0.7207

0.36037   1.45   0.2553 variety*Ca*Mg   2   1.1588

0.57938   2.34   0.1201

Error   22   5.4539   0.24790

Total   35   12.8831

Grand Mean 4.1028   CV 12.14

KNUST

Analysis of Variance Table for Redripe

Source   DF   SS   MS   F   P REP

2   7.997   3.99864 variety   1   0.467

0.46694   0.13   0.7213 Ca   1   1.198

1.19781   0.33   0.5687 Mg   2   11.189

5.59457   1.56   0.2317 variety*Ca   1   1.914

1.91361   0.53   0.4723 variety*Mg   2   2.450

1.22481   0.34   0.7138 Ca*Mg   2   4.196

2.09790   0.59   0.5648 variety*Ca*Mg   2   6.685

3.34259   0.93   0.4079

Error   22   78.706   3.57756

Total   35   114.802

Grand Mean 4.7731   CV 39.63

DRY WEIGHT

Analysis of Variance Table for Breaker

Source DF SS MS F P rep

2 0.5363 0.26813 variety 1 0.3563

0.35629 0.51 0.4835 Ca 1 0.5754

0.57538 0.82 0.3749 Mg 2 3.1528

1.57642 2.25 0.1294 variety*Ca 1 3.4263

3.42627 4.88 0.0378 variety*Mg 2 5.1511

2.57554 3.67 0.0421 Ca*Mg 2 2.1465

1.07323 1.53 0.2387 variety*Ca*Mg 2 0.3628

0.18142 0.26 0.7744 Error 22 15.4314

0.70143

Total 35 31.1388

Grand Mean 1.2236 CV 68.45

Analysis of Variance Table for Halfripe

Source DF SS MS F P rep

2 2.2341 1.11703 variety 1 0.0461 0.04607

0.08 0.7837 Ca 1 0.4287 0.42872 0.72

0.4058 Mg 2 0.0708 0.03540 0.06 0.9426

variety*Ca 1 1.7198 1.71977 2.88 0.1037

variety*Mg 2 2.0940 1.04702 1.75 0.1963

Ca*Mg 2 1.3855 0.69275 1.16 0.3317

variety*Ca*Mg 2 0.4611 0.23054 0.39 0.6841

Error 22 13.1285 0.59675

Total 35 21.5686

Grand Mean 1.1567 CV 66.78

KNUST

Analysis of Variance Table for Fullripe

Source DF SS MS F P rep

2 0.2416 0.12078 variety 1 1.3063

1.30633 1.35 0.2577 Ca 1 0.0007

0.00073 0.00 0.9783 Mg 2 0.4661

0.23304 0.24 0.7880 variety*Ca 1 0.1992

0.19915 0.21 0.6545 variety*Mg 2 2.3878

1.19389 1.23 0.3105 Ca*Mg 2 3.0710

1.53552 1.59 0.2270 variety*Ca*Mg 2 2.5433

1.27164 1.31 0.2889

Error 22 21.2832 0.96742

Total 35 31.4992

NYANSAPO WO SANE NO BADWENMA

Grand Mean 1.5985 CV 61.53

Analysis of Variance Table for Redripe

Source DF SS MS F P rep

2 0.1882 0.09408 variety 1 1.8254

1.82544 2.08 0.1630 Ca 1 0.1247

0.12465 0.14 0.7097 Mg 2 0.5277

0.26385 0.30 0.7430 variety*Ca 1 1.1921

1.19213 1.36 0.2559 variety*Mg 2 2.2453

1.12266 1.28 0.2976 Ca*Mg 2 1.0728

0.53642 0.61 0.5511 variety*Ca*Mg 2 0.2631

0.13154 0.15 0.8615

Error 22 19.2757 0.87617

Total 35 26.7150

Grand Mean 2.0941 CV 44.70

FIRMNESS

Analysis of Variance Table for Breaker

Source DF SS MS F P REP

2 1.0778 0.53892 variety 1 1.4534 1.45336

4.88 0.0379 Ca 1 1.7045 1.70448 5.72

0.0258 Mg 2 1.1484 0.57420 1.93 0.1694

variety*Ca 1 4.8645 4.86448 16.33 0.0005

variety*Mg 2 1.7721 0.88605 2.97 0.0719

Ca*Mg 2 0.6728 0.33642 1.13 0.3414

variety*Ca*Mg 2 2.9484 1.47420 4.95 0.0168

Error 22 6.5555 0.29798

Total 35 22.1974

Grand Mean 4.6435 CV 11.76

Analysis of Variance Table for Halfripe

Source DF SS MS F P REP

2 0.1817 0.09083 variety 1 0.5542 0.55420

4.23 0.0517 Ca 1 0.8100 0.81000 6.19

0.0209 Mg 2 2.6613 1.33065 10.17 0.0007

variety*Ca 1 0.0060 0.00605 0.05 0.8318

variety*Mg 2 0.9723 0.48614 3.71 0.0408

Ca*Mg 2 1.2946 0.64731 4.95 0.0168

variety*Ca*Mg 2 0.8723 0.43614 3.33 0.0544

Error 22 2.8798 0.13090
Total 35 10.2322

Grand Mean 3.5056 CV 10.32

Analysis of Variance Table for Fullripe

Source DF SS MS F P REP

2 0.00154 0.00077 variety 1 0.44444

0.44444 7.24 0.0133 Ca 1 0.00444

0.00444 0.07 0.7904 Mg 2 1.24747

0.62373 10.16 0.0007 variety*Ca 1 2.21679

2.21679 36.12 0.0000 variety*Mg 2 0.47056

0.23528 3.83 0.0373 Ca*Mg 2 0.36907

0.18454 3.01 0.0701 variety*Ca*Mg 2 0.41043

0.20522 3.34 0.0540

Error 22 1.35031 0.06138

Total 35 6.51506

Grand Mean 2.3296 CV 10.63

KNUST

Analysis of Variance Table for Redripe

Source DF SS MS F P REP

2 0.00821 0.00410 variety 1 0.06531

0.06531 1.45 0.2407 Ca 1 0.37346

0.37346 8.32 0.0086 Mg 2 0.07562

0.03781 0.84 0.4443 variety*Ca 1 5.29000

5.29000 117.78 0.0000 variety*Mg 2 0.28969

0.14485 3.23 0.0591 Ca*Mg 2 0.11191

0.05596 1.25 0.3072 variety*Ca*Mg 2 0.26722

0.13361 2.97 0.0719 Error 22 0.98809

0.04491

Total 35 7.46951

Grand Mean 2.3204 CV 9.13

MOISTURE CONTENT

Analysis of Variance Table for Breaker

Source DF SS MS F P rep

2 69.0 34.503 variety 1 78.6 78.605

0.29 0.5947 Ca 1 7.0 7.047 0.03

0.8731 Mg 2 959.7 479.826 1.78 0.1922

variety*Ca 1 940.2 940.178 3.49 0.0753

variety*Mg 2 1831.2 915.588 3.39 0.0519

Ca*Mg 2 489.8 244.913 0.91 0.4179

variety*Ca*Mg 2 138.3 69.137 0.26 0.7762

Error 22 5933.4 269.698

Total 35 10447.1

Grand Mean 48.862 CV 33.61

KNUST

Analysis of Variance Table for Halfripe

Source DF SS MS F P
rep 2 623.75 311.875 variety 1 2.29

2.291 0.01 0.9269 Ca 1 219.29 219.289

0.83 0.3735 Mg 2 494.06 247.030 0.93

0.4097 variety*Ca 1 457.77 457.768 1.72

0.2029 variety*Mg 2 641.44 320.718 1.21

0.3182 Ca*Mg 2 596.22 298.108 1.12

0.3436 variety*Ca*Mg 2 639.45 319.727 1.20

0.3193

Error 22 5846.67 265.758

Total 35 9520.93

Grand Mean 48.412 CV 33.67

Analysis of Variance Table for Fullripe

Source DF SS MS F P rep

2 822.6 411.313 variety 1 719.4 719.432

1.54 0.2282 Ca 1 53.5 53.460 0.11

0.7387 Mg 2 703.4 351.678 0.75

0.4836 variety*Ca 1 144.2 144.240 0.31

0.5845 variety*Mg 2 104.1 52.036 0.11

0.8953 Ca*Mg 2 1043.8 521.888 1.11

0.3459 variety*Ca*Mg 2 1069.7 534.875 1.14

0.3373

Error 22 10302.8 468.310

Total 35 14963.5

KNUST

Grand Mean 54.706 CV 39.56

Analysis of Variance Table for Redripe

Source DF SS MS F P rep

2 7.56 3.778 variety 1 431.71 431.712

3.96 0.0592 Ca 1 3.64 3.641 0.03

0.8567 Mg 2 3.45 1.727 0.02 0.9843

variety*Ca 1 96.53 96.525 0.89 0.3570

variety*Mg 2 419.71 209.856 1.92 0.1697

Ca*Mg 2 163.23 81.615 0.75 0.4847

variety*Ca*Mg 2 16.08 8.040 0.07 0.9291

Error 22 2398.55 109.025

Total 35 3540.46

Grand Mean 65.129 CV 16.03

PERICARP THICK NESS

Analysis of Variance Table for Breaker

Source DF SS MS F P REP

2 0.39989 0.19995 variety 1 0.04646

0.04646 0.24 0.6298 Ca 1 0.03568

0.03568 0.18 0.6726 Mg 2 0.94154

0.47077 2.42 0.1121 variety*Ca 1 0.31360

0.31360 1.61 0.2174 variety*Mg 2 0.18365

0.09182 0.47 0.6298 Ca*Mg 2 0.97796

0.48898 2.51 0.1039 variety*Ca*Mg 2 0.07760

0.03880 0.20 0.8206

Error 22 4.27787 0.19445

Total 35 7.25425

Grand Mean 5.0781 CV 8.68

Analysis of Variance Table for Halfripe

Source DF SS MS F P REP

2 13.793 6.8964 variety 1 8.006 8.0058

1.00 0.3276 Ca 1 24.618 24.6181 3.08

0.0930 Mg 2 21.484 10.7422 1.35

0.2811 variety*Ca 1 7.468 7.4681 0.94

0.3440 variety*Mg 2 13.232 6.6159 0.83

0.4498 Ca*Mg 2 14.976 7.4878 0.94

0.4066 variety*Ca*Mg 2 30.065 15.0323 1.88

0.1759

Error 22 175.666 7.9848

Total 35 309.307

Grand Mean 5.5060 CV 51.32

Analysis of Variance Table for Fullripe

KNUST

Source DF SS MS F P REP

2 1.1771 0.58855 variety 1 0.7037

0.70373 1.80 0.1932 Ca 1 0.7225

0.72250 1.85 0.1876 Mg 2 3.8909

1.94543 4.98 0.0164 variety*Ca 1 1.6641

1.66410 4.26 0.0510 variety*Mg 2 0.9252

0.46260 1.18 0.3247 Ca*Mg 2 3.2241

1.61203 4.13 0.0301 variety*Ca*Mg 2 0.3530

0.17651 0.45 0.6422

Error 22 8.5936 0.39062

Total 35 21.2542

Grand Mean 5.1583 CV 12.12

Analysis of Variance Table for Redripe

Source DF SS MS F P REP

2 0.1676 0.08379 variety 1 0.0363 0.03631

0.18 0.6779 Ca 1 2.4911 2.49114 12.16

0.0021 Mg 2 2.7339 1.36696 6.67 0.0054

variety*Ca 1 0.0477 0.04767 0.23 0.6344

variety*Mg 2 0.0484 0.02418 0.12 0.8893

Ca*Mg 2 0.8991 0.44956 2.19 0.1353

variety*Ca*Mg 2 1.2550 0.62752 3.06 0.0671

Error 22 4.5085 0.20493

Total 35 12.1876

Grand Mean 5.3214 CV 8.51

KNUST
WJ SANE NO BADWENMA

FRUIT DIAMETER

KNUST

Analysis of Variance Table for Diameter

Source DF SS MS F P rep 2

4.029 2.0144 variety 1 50.526 50.5264 26.28

0.0000 Ca 1 25.769 25.7689 13.40 0.0014

Mg 2 76.076 38.0378 19.78 0.0000

variety*Ca 1 12.844 12.8437 6.68 0.0169

variety*Mg 2 106.794 53.3970 27.77 0.0000

Ca*Mg 2 99.037 49.5187 25.76 0.0000

variety*Ca*Mg 2 69.910 34.9548 18.18 0.0000

Error 22 42.299 1.9227

Total 35 487.283

Grand Mean 39.171 CV 3.54

ROTS

Analysis of Variance Table for rot

Source DF SS MS F P rep

2 147.39 73.70 variety 1 1111.11 1111.11

9.02 0.0065 Ca 1 90.70 90.70 0.74

0.4001 Mg 2 351.47 175.74 1.43 0.2614

variety*Ca 1 566.89 566.89 4.60 0.0432

variety*Mg 2 79.37 39.68 0.32 0.7279

Ca*Mg 2 351.47 175.74 1.43 0.2614

variety*Ca*Mg 2 351.47 175.74 1.43 0.2614

Error 22 2709.75 123.17

Total 35 5759.64

Grand Mean 17.460 CV 63.56

Analysis of Variance Table for TRANSFORMED rot

Source DF SS MS F P rep

2 1.251 0.6254 variety 1 20.185

20.1854 7.13 0.0140 Ca 1 0.730

0.7296 0.26 0.6168 Mg 2 11.419

5.7093 2.02 0.1571 variety*Ca 1 11.984

11.9839 4.23 0.0517 variety*Mg 2 1.618

0.8089 0.29 0.7543 Ca*Mg 2 7.003

3.5015 1.24 0.3099 variety*Ca*Mg 2 8.660

4.3299 1.53 0.2390

Error 22 62.309 2.8322

Total 35 125.158

Grand Mean 3.8057 CV 44.22

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Analysis of Variance Table for shrink

Source DF SS MS F P rep

2 1031.7 515.873 variety 1 141.7

141.723 0.49 0.4896 Ca 1 5.7

5.669 0.02 0.8895

Mg 2 419.5 209.751 0.73 0.4929

variety*Ca 1 141.7 141.723 0.49 0.4896

variety*Mg 2 487.5 243.764 0.85 0.4413

Ca*Mg 2 691.6 345.805 1.20 0.3188

variety*Ca*Mg 2 1576.0 787.982 2.75 0.0862

Error 22 6315.2 287.054

Total 35 10810.7

Grand Mean 36.111 CV 46.92

Analysis of Variance Table for TRANSFORMED shrink

Source DF SS MS F P rep

2 7.147 3.57344 variety 1 2.063 2.06253

0.56 0.4633 Ca 1 0.411 0.41080 0.11

0.7422 Mg 2 7.098 3.54885 0.96

0.3989 variety*Ca 1 4.512 4.51228 1.22

0.2815 variety*Mg 2 5.419 2.70954 0.73

0.4924 Ca*Mg 2 3.401 1.70031 0.46

0.6377 variety*Ca*Mg 2 15.208 7.60405 2.05

0.1521

Error 22 81.448 3.70216

Total 35 126.706

Grand Mean 5.7525   CV 33.4

KNUST