KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY
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DEPARTMENT OF HORTICULTURE

EFFECT OF PLANTING DATE AND POULTRY MANURE ON FLOWER ABORTION, YIELD AND POST HARVEST QUALITY OF THREE TOMATO VARIETIES IN GHANA (F1 KAIRA, PECTOMECH AND PECTOFAKE)

BY

KHADDY BOJANG SAIDY

JULY, 2015

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BY

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JULY, 2015

DECLARATION

I hereby declare that except for references to other people's work which have been duly acknowledged, this work submitted to the Board of Postgraduate Studies, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana is the result of my own research work and investigation and has not been presented for any other degree in this University or elsewhere except where due acknowledgement has been made in the text.

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DEDICATION

I dedicate this dissertation to my mother, Binta Darboe, my late father Yankuba Demba Bojang, my husband Ebrima ML Saidy, my daughters Fatoumata Nogoi and Binta Saidy, my sons Abba (Sherriffo) and Musa Saidy

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ABSTRACT

The study aimed at evaluation of different planting dates and levels of poultry manure on flower abortion, yield and fruit quality of three tomato varieties. A factorial experiment with Randomized Complete Block Design with four replications was adopted for the field experiment and Complete Block Design for the laboratory experiment. Planting was done at three different dates with two weeks interval. Four different manure levels and three tomato varieties were used. The addition of poultry manure had significant effect on the growth and yield of the three tomato varieties. There were significant differences (p>0.05) between the varieties tested and the different levels of manure. Yield increased significantly with increase in the application of poultry manure with significant differences (p>0.05) between the manure levels. Addition of poultry manure at 2,4,and 6tons/ha increased tomato yield by 28.04, 38.09 and 61.90% for 2, 4 respectively. Other parameters such as branching, number of fruits per plant, girth diameter, plant height, fruit dry matter content, total soluble solids and fruit firmness increased as the amount of poultry manure applied increased. Planting date had significant effect on the number of fruits, flower abortion, plant height and pest and disease infestations. The early sowing date (March 26th) showed higher number of branches compared to the late sowing dates but not significantly different (p>0.05). Planting of tomato on the 26th of March with 6 tons/ ha of poultry manure resulted in the highest fruit yield/ ha. The yield of the tomato decreased with delay in planting date. The cultivars had significant effect on growth as well as quality. This may be due to differences on growth habit of genotypes. Pectofake, the local variety had the highest fruit weight but lowest means for fruit pericarp thickness, firmness, and total soluble solids. Pectofake recorded the best performance compare to F1 Kaira and Pectomech.

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CHAPTER ONE

1.0 INTRODUCTION

Agriculture is the main driving force behind Ghana's economy, accounting for approximately forty two percent of the country's GDP and employing about fifty four percent of its workforces. In recent years, the Government is encouraging the development of the non-traditional agricultural sector in order to diversify its export base. Special emphasis is placed on horticultural production in recognition of Ghana's natural and competitive advantages in the area (GIPC, 2001).

Tomato (*Solanum esculentum* Mill.) is one of the most widely used food crops in world vegetable economy (Chapagain and Wiesman, 2004). In Ghana, it is now the number one vegetable consumed (Schippers, 2000; Osei *et al*; 2010). It is almost an obligatory ingredient in the daily diets of people across all regions (Ellis *et al*., 1998). Tomatoes is a major source of lycopene, a dietary carotenoid found in high concentrations in the fruit (Di Mascio *et al*., 1998). Tomato contains other important chemical compounds that play roles in the prevention of cancer, heart disease, cataracts and many other health problems (Beecher, 1998).

Tomato production has been an important source of income for smallholder farmers for many years. In recent years, domestic tomato production has seen a rise across Ghana but local production is not able to meet the domestic high demand because tomatoes of the right quality and quantity for commercial agro processing are not being grown. Consequently, this has resulted in tomatoes been often imported, mainly from Burkina Faso (Horna *et al.,* 2006) to meet the domestic demand. This large import deficit has become a drain on the already scarce foreign exchange resources of the country (Al-Hassan *et. al*. 2007). One of the key issues for tomato farmers in Ghana is high per-unit input costs. Fertilizer is the largest component of purchased inputs for Ghana's tomato farmers (Robinson and Kolavalli, 2010). Furthermore, climate change has resulted in farmers facing uncertainties as regards the sowing periods for good yields. These two issues have become limiting factors to increased production of tomato in Ghana. Through the application of appropriate measures, such as alternative sources of fertilizer and conducive planting periods these factors could be eliminated.

Objectives:

The general objective of this study was therefore to determine the effects of poultry manure and planting dates on the growth , yield and post harvest quality of the three tomato varieties.

Specifically, the objectives were to determine the

1. effect of poultry manure on the growth and yield of three varieties of tomato
2. effect of time of planting on the growth and yield of three varieties of tomato
3. combined effect of poultry manure and time of planting on the growth and yield of three varieties of tomato
4. combined effect of poultry manure and time of planting on the postharvest quality and shelf life of the three tomato varieties

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin and importance of tomato

In the family *Solanaceae*, *Lycopersicon esculentum* Mill, tomato originated from Peru but was domesticated in Mexico (Peet, 2001). Tomato was introduced to Europe in 1544. The crop was only slowly accepted in Europe because it was thought to be poisonous and cause cancer (Peet, 2001).

Tomato (*Solanum lycopersicum* L.) is one of the most important vegetable crops grown throughout the world and ranks next to potato in terms of production area but ranks first as a processing crop (Mohammed, *et al* 2013). It is a major horticultural crop with an estimated global production of over 120 million metric tons (FAO. 2007). It is one of the most widely used food crops in the world vegetable economy (Chapagain and Wiesman, 2004). Commercial vegetable production is gaining prominence in Ghana. This is partly due to the production of crops with export potential as well as public education from Health experts and Nutritionists on the need to consume more vegetables in the diet to avoid diseases like cancer, hypertension, coronary disease, diabetes, hepatitis B and anaemia (Gopalan, 2004). It is proven that daily intake of fresh or processed tomatoes by human decreases risk of chronic diseases, like cardiovascular diseases and cancer (Ilahy *et al*., 2011). Tomato fruits are the main source of lycopene, an important source of β-carotene, ascorbic acid, vitamin E and phenolic compounds, which give benefits to humans because of antioxidant activity (Balestrieri *et al*., 2004; Frusciante *et al*., 2007; Guil-Guerrero and Rebolloso-Fuentes, 2009; Leonardi *et al*., 2000; Mueller, 1997; Raffo *et al*., 2006; Rosales *et al*., 2011; Yahia *et al*., 2001). Tomato fruit sensory quality relates to several attributes, like dry matter, sugar content and juice acidity (Kowalczyk *et al*., 2011). Flavour results from combination of odor and taste and is in a large amount based on the balance between sugars and organic acids contents (Oms-Oliu *et al*., 2011).

2.2 General characteristics of tomato

The tomato plant is unusually sensitive to rapidly changing conditions in the surrounding environment, radiation intensity, air temperature and humidity, and that in the rooting medium, moisture and temperature levels, primarily affect fruit set and development (Journal of Crop Improvement volume 28, 2014). When Solar Radiation has low intensity or low hours of radiation, plant vegetative growth will be slow and fruit set are poor; with high light intensity also, poor fruit set also occurs. Light intensity has been shown to affect the net assimilation rate of crops (Blackman & Wilson, 1951) According to (Ozores *et al*,. 2013), best growing environmental conditions are full morning sun, shade from high moon light intensity and partial shading in the late afternoon when light intensity radiation is high. Fresh market tomatoes are usually marketed by fruit type. These types include full-size globe (red or yellow), plum (Roma), and cherry. Consumers buy tomatoes primarily for their appearance but are attracted to repeat purchases by flavor and quality. Tomatoes are very sensitive to mishandling and improper storage conditions. Because they can be injured by either low or high temperatures, proper postharvest handling and storage methods are essential for maintaining acceptable quality and promoting long shelf life.

2.3 Soils and environmental conditions for tomato production

Many studies indicate that the key factor for plant growth, yield, fruit quality and storage ability is the growing medium used during production and the surrounding environment. Correct application of organic fertilizer prevents symptoms of deficiency in the crops during the growing season. According to Rob den Ouden (2009-2014), this positive effect of organic fertilizer means a considerable saving in mineral fertilizers, and a reduction of mineral fertilizers application in the soil is good for the environment and help preventing soil alkalinity. Using an organic fertilizer can lead to an increase in the microbiological activity in the soil. Organic substances are broken down by the soil life into humid acids and amino acids. According to (Erenstein *et al*. 2005), the crops are best when grown in welldrained fertile soils with good moisture retaining capacity and a relatively high level of organic materials.

However many cultivars tolerate a range of soil conditions (Rice *et al*., 1991). Slightly acid soils with pH of 5.0-6.5 are suitable. Low soil temperatures retard the growth of seedlings and absorption of minerals (Peet, 2001). High air temperatures above

27^0C can cause pollen sterility and high night temperatures adversely affect flower initiation. Night temperatures of about 19-20^0C are considered ideal for most cultivars (Peet, 2001). A diurnal variation of at least 5-6^0C is considered necessary for optimum growth and development (Rice *et al*., 1991). High temperatures combined with low relative humidity can seriously affect fruit setting. Both high and low temperatures can affect fruit quality, particularly the color of the fruit (Peet, 2001). Fruits rarely ripen fully during wet periods and production is generally higher in the dry season with irrigation (Peet, 2001). Elevations of up to 2000 meters are suitable for cultivations, although yields are generally low mainly due to a lack of diurnal temperature variation and high humidity that encourages leaf diseases (Rice *et al*., 1991).

Research has shown that the ability of a crop plant to resist or tolerate insect pests and diseases is tied to optimal physical, chemical and mainly biological properties of the soil (Patriquin *et al*., 1995). Reduced susceptibility to pest may be a reflection of differences in plant health, as mediated by soil fertility (Alteri and Nicholls, 1990). Soil fertility practices can impact the physiological susceptibility of crops to insect pest by either affecting the resistance of individual plant to attack or by altering plant acceptability to certain herbivores (Patriquin *et al*., 1995). They also noted that organic fertilizer agriculturists have long maintained that pest and disease problems are indicative of soil fertility problems. A healthy soil produces plants that are resistant to pests and diseases and organic manure produces a healthy soil (Balfour, 1975). It has also been noted that nutritional status influences such factors as the growth pattern and onset of senescence of epidermal cells and degree of humunification, sugar concentration in the apoplast, amino-N in phloem sap, and levels of secondary compound which in turn affect resistance to pest and disease (Patriquin *et al*., 1995). Their report also showed that a strong deficiency or excess of nitrogen encourages certain pest and disease and that many factors influencing susceptibility of pests and diseases do so through their effects on plant nitrogen metabolism. Furthermore they noted that susceptibility of plants to obligating parasitic fungi such as stem rusts tends to increase with nitrogen supply, while susceptibility to facultative parasites and most bacterial diseases decrease with increase nitrogen supply.

High concentration of potassium tends to increase resistance to both groups of disease organisms (Marschner, 1986). Mineral imbalances or excesses could occur under certain types of organic management, such as where large amount of poultry manure or compost are used (Patriquin *et al*., 1995). Chemical fertilizer could dramatically influence the balance of nutritional elements in plants, and it is likely that their excessive use would create nutrient imbalances which in turn, could reduce resistance to insect pests (Patriquin *et al*., 1995). They noted that while the amount of nitrogen immediately available to the crop may be lower when organic manure are applied as against when chemical fertilizer is used, the overall nutritional status of the crop appears to be improved.

2.4 Some challenges associated with tomato production

Excessive rainfall can harm a tomato crop, particularly if it is not staked, due to the spread of leaf diseases in humid conditions (Rice *et al*., 1991).

A lot of physiological problems are associated with tomatoes (Boyhan and Kelley, 2003) due mainly to specific adverse environmental conditions.

2.4.1 Blossom-End Rot

Blossom-end rot is a calcium deficiency that occurs at the blossom end of the fruit (Boyhan and Kelley, 2003). It is a condition where by black necrotic sunken tissue(s) are formed at the blossom end of the fruit. The necrotic tissue formed at the blossom end of the fruit does not change the entire nutritive values of the fruit, but only affects that portion which can make the fruit unattractive to consumers. Blossom-end rot develops very early in fruit formation when the fruit is smaller than a fingernail, which is a critical time for calcium deposition in newly forming tissue. Calcium is relatively immobile in plants. Once it becomes part of the plant tissue in one location, it cannot be easily moved to new developing tissue (Boyhan and Kelley, 2014). Furthermore, calcium moves in the water stream of the plant's vascular tissue. So during hot, dry conditions with high transpiration, calcium uptake may be high but may not be moving laterally into forming fruit. This results in deficiency in these developing tissues even though there is sufficient calcium present in the soil. Blossom end rot is common in un-staked and un pruned plants.

The problem can be alleviated with even moisture regime during plant growth. Irregular watering as well as over-watering tend to aggravate the problem. Exogenous applications of calcium as foliar sprays have been suggested to alleviate the problem (Boyhan and Kelley, 2014).

2.4.2 Flower abortion

Tomato is a warm season crop and needs relatively moderate temperatures to set fruit. Night time temperatures above 21°C will cause flower abortion which in turn will reduce yields (Boyhan and Kelley, 2014). In extreme temperatures such as high daytime temperatures (above 29 °C), high night-time temperatures (above 21° C), or low night time temperatures (below 13° C) flower abortion is high (Ozores *et al*, 2013). The ideal humidity range is between 40 and 70%. If humidity is either too high or too low, it interferes with the release of pollen and its ability to stick to the stigma. In fact, anything that interferes with the pollination and fertilization processes may result in flower loss (Rabinowitch *et al*, 2010). When pollination fails, fruit set becomes absent, and therefore the flowers die and drop. This condition can affect other vegetables such as peppers, snap beans, and other fruiting ones. In tomatoes, flower abortion is usually preceded by the yellowing of the pedicle. Tomato flowers must be pollinated within approximately fifty hours of opening or they will abort and drop off. This is about the time it takes for the pollen to germinate and travel up the style to fertilize the ovary at temperatures above 13°C (Ozores *et al*, 2013). Tomatoes needs wind, humans, or insects to move the pollen from anthers to stigma if this is not possible, flower abortion occurs. Low or high nitrogen application can causes flower abortion. Also when a tomato plant has a lot of flowers and the amount of nutrient available in the growing medium is not sufficient to support all, the plant will automatically abort some of them (Ozores *et al*, 2013).

2.4.3 Fruit Cracking

Tomato fruit crack under certain conditions. There are two different types of cracking — radial and concentric — both of which occur at the stem end. Radial cracking is more common and usually occurs during periods of high temperatures (at or above 32° C.), prolonged rain or wet soil when fruit will rapidly expand and often crack. This is particularly prevalent after a long period of dry spell. Maintaining even moisture conditions, avoiding excessive pruning, and having a heavy fruit load will help prevent this problem. Some tomato varieties are resistant to cracking and therefore varietal selection can also help alleviate this problem.

Concentric cracking is also caused by rapid growth, but generally occurs when there are alternating periods of rapid growth followed by slower growth. This can occur with wet/dry cycles or cycles of high and low temperatures. Generally this type of cracking occurs as fruits are close to maturation. Even moisture throughout the growing period will help alleviate this problem.

2.4.4 Puffiness

The general appearance of the fruit looks good but when cut there is little or no gel or seed, the fruit is nearly empty. This condition affect fruits that develop under very cool or very hot temperatures (below13° C and above 32° C.) respectively, which interferes with normal seed set (Boyhan and Kelley, 2014). Tomatoes are self-pollinated but require some disturbance of the flower in order for the pollen to be shaken onto the stigma. This movement of pollen from the anther to the stigma by human through normal cultural practices like weeding, staking, pruning or even during watering and spraying. Wet, humid and cloudy weather interfere with insects pollination so pollen may not be shaded well. Low temperatures will slow the growth of pollen tubes but excess nitrogen can also influence this condition.

2.4.5 Some common diseases of tomato

Plant diseases are one of the most important limiting factors to tomato production (Langston, 2003). The hot, humid climate coupled with frequent rainfall and mild winters favour the development of many disease pathogens that cause diseases.

2.4.6 Some common bacterial diseases of tomato

2.4.6.1 Bacterial spot

Bacterial spot is the most common and often the most serious disease affecting tomatoes. This disease is caused by the bacterium *Xanthomonas axonopodis* pv. *vesicatoria*. Bacterial spot lesions can be observed on leaves, stems and fruit and occur during all stages of plant growth. Leaf lesions usually begin as small water-soaked lesions that gradually become necrotic and brown in the center (Langston, 2003). During wet periods the lesions appear more water-soaked. Lesions generally appear sunken on the upper surface and raised on the lower surface of infected leaves. During periods of favourable weather, spots can coalesce and cause large areas of leave to lose their green pigmentation resulting in premature leave dropping.

The bacterium is primarily seed-borne and most epidemics can be traced back directly or indirectly to an infected seed source. Infected seedlings carry the disease to the field, where it spreads rapidly during warm, wet weather. Workers working in wet fields can also be a major source of disease spread. Prevention is the best method for suppressing losses to bacterial spot. Purchase seed from companies that produce the seed in areas where the disease is not known to occur. Hot water seed treatment can also be used, and tomato seed can be soaked in water that is 50° C for 25 minutes to kill the bacterium.

Unlike pepper, tomatoes have no commercially available cultivars resistant to bacterial spot. Rotate away from fields where tomatoes have been grown within the past year and use practices that destroy volunteer plants that could allow the disease to be carried over to a subsequent crop. Copper fungicides used in conjunction with Maneb will suppress disease losses if applied on a preventive schedule with a sprayer that gives adequate coverage.

2.4.6.2 Bacterial wilt

Bacterial wilt, caused by *Ralstonia solanacearum*, is a devastating bacterial disease of tomatoes worldwide. This bacterium can last in the soil for several years and has been responsible for taking whole fields out of production. Bacterial wilt is recognized by a rapid wilting of the tomato plant, often while the plant is still green. Wilted plants will eventually die. A quick diagnostic tool is to cut a lower stem of a suspected infected plant and place it in a clear vial or glass of water and watch for the opaque, milky bacterial streaming that comes from the cut area.

Bacterial wilt is not easily controlled by fumigation or chemical means. There are few commercially available cultivars with resistance to bacterial wilt. The best control tool is to rotate away from infested fields for several years.

2.4.6.3 Bacterial speck

Bacterial speck, caused by *Pseudomonas syringae* pv. Leaflet lesions are very small, round and dark brown to black. During favourable weather conditions the lesions can coalesce and kill larger areas of leaf tissue. Bacterial speck causes oval to elongated lesions on stems and petioles. Tomato fruit may have minute specks with a greener area surrounding the speck.

Control measures are similar to bacterial spot.

2.4.7 Some Common Virus Diseases of Tomato

Virus diseases have been a severe limiting factor in tomato production. Most virus diseases cause stunting, leaf distortion, mosaic leaf discoloration, and spots or discoloration on fruit. The distribution of virus-infected plants is usually random with symptomatic plants often bordered on either side by healthy, non-symptomatic plants. Virus diseases are almost always transmitted by insect vectors, and the severity of a virus disease is usually tied to the rise and fall in the populations of these vectors from season to season and within a given season.

2.4.7.1 Tomato spotted wilt virus (TSWV)

It is one of the most common viruses affecting tomato. This virus is transmitted by thrips and can affect tomato at any stage of development. The extensive host range of TSWV in weeds allows for a continual source of inoculums for infection. As with any virus disease, however, early infections tend to cause more yield losses than those occurring later in plants' development. TSWV causes plant stunting, ring spots and bronzing on infected plants. Tomato fruit produced on infected plants may be misshapen, have dark streaks or have chlorotic spots.

2.4.7.2 Cucumber mosaic virus (CMV)

It is a very common disease of tomato and can be very devastating where it occurs. This virus is transmitted by aphids and can be maintained in several weed species that surround production fields. The characteristic symptoms for CMV are severely stunted, distorted and strapped (faciated) leaves, stems and petioles. Symptoms of CMV often resemble herbicide injury. Few options are available for suppressing losses to CMV, but destruction of weed hosts that harbour the virus will help in suppressing disease spread.

2.4.7.2 Tomato yellow leaf curl virus (TYLCV)

It is a very serious virus disease that is transmitted by whitefly, the disease is higher in times when the white fly population is also high. The affected plants are normally stunted with little or no fruit, with few chlorosis leaves.

2.4.8 Some common fungal diseases of tomato

2.4.8.1 Early blight

It is caused by *Alternaria solani* is perhaps the most common fungal disease of tomato foliage. Leaf symptoms appear as round to oblong, dark brown lesions with distinct concentric rings within the lesion. Lesions are generally surrounded or associated with a bright yellow chlorosis. Stem lesions are slightly sunken, brown and elongated with very pronounced concentric rings. Fruit may become infected around the calyx, and a velvety spore mass can often be observed on fruit lesions. The disease is introduced by wind or rainsplash and is carried over to subsequent crops on infested debris. Wet, humid weather favours disease development and the fungus spores are spread mainly by wind. Unless controlled, it causes severe defoliation. Resistant varieties are available to avoid losses to early blight. Rotation and deep turning are important for reducing initial inoculums.

2.4.8.2 Late blight

It is caused by *Phytopthora infestans* is probably one of the best known tomato diseases worldwide. This disease causes dark, water-soaked, greasy lesions on stems and foliage. A whitish-gray, fuzzy sporulation can be seen on the undersides of leaf lesions and directly on stem lesions during periods of high moisture. A soft rot of fruit can also be observed. Warm days and cool nights coupled with adequate moisture favour the spread and infection of the late blight pathogen. Plant resistance to this disease is available but does not play a major role in disease control. Destroying plant debris and rotating away from fields with a history of the disease is necessary for the control of this disease. Preventive fungicide sprays are generally effective especially when the disease is endemic.

2.4.8.3 Fusarium wilt

It is caused by *Fusarium oxysporum* f.sp. *lycopersici*. is a soil borne disease of tomatoes that is generally a problem in specific fields where the pathogen has been introduced. The disease is initially brought into a field on infested seed, plant stakes, transplants or infested soil on equipment. Symptoms usually appear during hot weather and after fruit set has begun. Symptoms appear as a yellowing and wilting on one side of the plant at first, usually during the hottest part of the day, followed by the eventual complete yellowing and wilting of the plant and the entire plant will. Vascular discoloration is often observed on stems above the ground. This fungus can stay in the soil in a resting state for several years, and rotation away from these fields for 5-7 years will lessen the severity but will not completely eliminate the disease. Fumigation really only delays disease onset and may lessen the total disease incidence. Preventing the disease from getting into the field is the best control measure, followed by the use of resistant varieties.

2.4.9 Nematodes

Root-knot nematodes (*Meloidogyne* spp) can cause serious economic damage to tomatoes. They live in the soil and feed on the roots of tomato forming knots that blocks water and nutrient from passing through the root system to other parts of the plant and also allow the establishment of other disease. Plants affected by the root knot nematodes are stunted in growth with pale green to light yellow leaves. The most effective way of control is by avoiding the infected area completely, or treat infected area with chemical nematicides before tomatoes are planted.

2.4.10 Some common insect pests of tomato

Insect pests can cause damage tomato plant throughout the growing season, but severity varies with location and time of year. While many insects that feed on tomato are only occasional pests a few species are common and occur every season. The severity of damage depends on the insect population and the environmental factors. With most insects, outbreaks are difficult to predict, and it is even more difficult to predict if control measures will be required. Research has shown that the ability of a crop plant to resist or tolerate insect pests and diseases is tied to optimal physical, chemical and mainly biological properties of the soil (Patriquin *et al.*, 1995). Reduced susceptibility to pest may be a reflection of differences in plant health, as mediated by soil fertility (Alteri and Nicholls, 1990). Soil fertility practices can impact the physiological susceptibility of crops to insect pest by either affecting the resistance of individual plant to attack or by altering plant acceptability to certain herbivores (Patriquin *et al*., 1995).

Many workers had amply illustrated the increased susceptibility effect of N-fertilization to insect infestation. Patriquin *et al.,* (1995) reported that many of the factors influencing susceptibility to pest and diseases do so through their effects on plant N-metabolism. Frequent or scheduled spraying is necessary for insect management because a variety of insects attack tomato. Scouting two to three times per week, however, allowing for early detection of infestations and timely application of pest specific control measures, is the most cost-effective management strategy.

2.4.10.1 Thrips

They may be present in tomato fields throughout the growing season, but they are more common during the rains. Prior to plants blooming, tobacco thrips generally dominates the population since this species readily feeds and reproduces on foliage. Flower thrips species

populations can increase dramatically once blooming and pollen availability increases. Plant injury is caused by both nymphs and adults puncturing leaf and floral tissues and then sucking the exuding sap. This causes reddish, grey or silvery speckled areas on the leaves. With severe infestations, these areas can interfere with photosynthesis and result in retarded growth. Heavy infestations during the bloom stage may cause damage to developing fruit through egg laying. This damage appears as dimples with necrotic spots in the centre and may be surrounded by a halo of discoloured tissue. To prevent direct damage, apply insecticides when twenty percent (20%) of plants show signs of thrips damage, or when five
(5) or more thrips per bloom are found.

2.4.10.2 Aphids: Aphids or plant lice are small, soft-bodied insects that may feed on tomato plants from time of planting until last harvest. Aphids cluster in shaded places on leaves, stems and blossoms while winged migrants move from field to field spreading virus diseases. Large populations of aphids on young plants can cause wilting and stunting but rarely occur.
At harvest, infestations can represent a contamination both through their presence and through production of honeydew, which gives rise to sooty mold.

2.4.10.3 Leaf miners: Adult leaf miners are tiny, shiny, black flies with yellow markings. Adult female flies lay eggs within the leaves, and white to pale yellow larvae with black mouthparts mine between the upper and lower leaf surface for about 5 to 7 days before dropping to the ground to pupate (Alton N. Sparks, Jr., 2014). The leaves are greatly weakened and the mines may serve as points where decay and disease may begin. With severe infestations, heavy leaf loss may lead to sun scald of fruit (Sparks, 2014).

Several parasites attack this pest and can keep leaf-miner populations under control. Leafminers rarely pose a serious threat to tomato production except in fields where their natural enemies are reduced by early, repeated insecticide applications (Sparks, 2014).

2.4.10.4 Spider Mites: Spider mites appear to be developing into a more consistent pest in Solanaceae family. They generally feed on the underside of leaves, but can cover the entire leaf surface when populations are high. The minute eight-legged mites appear as tiny, reddish, greenish or yellow moving dots on the undersides of leaves. Because of their size, the first detection of spider mite infestations is usually their damage to the leaves. Leaves of tomato plants infested with spider mites are initially lightly stippled with pale blotches. In heavy infestations, the entire leaf appears light in colour and dries up, often turning reddishbrown in blotches or around the edge and may be covered with webbing (Sparks, 2014).

2.4.10.5 Whiteflies: Adult whiteflies are tiny (about ⅛ inch) insects with white wings, a yellow body and piercing-sucking mouthparts. Adults are found on the underside of leaves, where they feed and lay eggs. While adults can cause direct damage by feeding, typically the nymphs are the more damaging stage.

Whiteflies, particularly the sweet potato or silver leaf whitefly, can be a severe pest in tomatoes grown in the cool season . At much lower densities, however, this pest causes irregular ripening of fruit and can transmit severe viral diseases, including tomato yellow leaf curl (Sparks, 2014).

Preventive treatments with systemic soil-applied insecticides which may require additional foliar treatments are effective in the control of whiteflies.

2.4.11 Weeds

Weed control is an important cultural practice which can increase production and productivity. Weeds compete with plant for sunlight, mineral nutrients, water and space. Weeds harbour pest and even contaminate the produce during harvesting. If weeds are not carefully control , it can lead to low yield **(**Culpepper, 2014) The effective way of weed control is the planting of healthy and vigorous seedlings that can grow faster than the weeds and form canopy to suppress their growth (Culpepper, 2014)

2.5 Effect of poultry manure

Organic manure has long been used to produce healthy soils (Balfour, 1975) which ensure quality and healthy plants capable of enhancing plant resistance to pests and diseases (Phelam *et al.*, 1995).

Animal manures have been used for plant production effectively for centuries. According to Echezona and Nganwuchu (2006**),** farmers of today find themselves unable to produce their crops economically without adding to their soils those elements that are limiting to the growth and productivity of their crop. Weil and Kroontje (1979) found the application of poultry manure at low rates (below 20 t ha^{-1}) very useful in boosting yield, but at higher rates (above 20 t ha^{-1}) phytotoxic quantities of ammonium nitrate and salt are released which adversely affect crop production.

Application of poultry manure and other farm wastes have been found to increase the carbon content, water holding capacity, aggregation of the soil and a decrease in the bulk density of the soil (Weil and Kroontje, 1979). They also indicated that the agronomic importance of the use of organic waste is essential in improving crop yield thereby reducing the use of inorganic

fertilizer. In Nigeria, interest in the use of organic manure is increasing. Its value, particularly in vegetable crop production has been recognized (Asiegbu and Uzo, 1984). In addition, manures supply other nutrients and serve as soil amendments by adding organic matter (Ouda and Mahadeen, 2008). Organic matter persistence in soil will vary with temperature, drainage, rainfall and other environmental factors. Organic matter in soil improves moisture and nutrient retention and soil physical properties (Arisha and Bradisi,
1999). The utilization of manure is an integral part of sustainable agriculture (Anonymous, 2008). Chicken manure is often produced in areas where it is needed for pastures and crop fertilization. The increased size and frequent clean out of many poultry operations make poultry manure available in sufficient quantities and on timely basis to supply most fertilizer needs (Eliot, 2005). When properly applied, chicken manure can be a valuable resource for grass, small grains and other crop production. The economics of using chicken manure varies considerably. Poultry litter is made out of raw poultry manure and bedding materials such as sawdust, wood shavings, grass cuttings, banana leaves or rice hulls. This combination provide an excellent source of nitrogen (N), phosphorus (P), potassium (K) and sulfur (S) (Anonymous, 2008).

Poultry manure contains high percentage of nitrogen and phosphorus for the healthy growth of plants (Ewulo, 2005). Nitrogen is equally said to be the motor of plant growth (IFA, 2000). Organic matter is the ultimate determinant of the soil fertility in most tropical soils and the fertility of the soil could be sustained with the addition of poultry manure (Ikpe and Powel, 2002). The application of organic manure has been observed to consistently increase the yields of horticultural crops such as eggplant (*Solanum melongena*), pepper (*Capsicum annum L.*) and tomatoes (*Lycopersicon esculentus*). Aliyu (2000) obtained highest yields of pepper with 5t farmyard manure (FYM) + 5t of poultry manure + 50 kg N/ ha or 10t of FYM + 5t of poultry manure. Lombin and Abdullahi, (1997) recommended 3 - 7 t/ ha of organic manure for maize. According to Agbede *et al* (2008) poultry manure increased plant N, P, K, Ca and Mg status by leaf analysis of sorghum. Poultry manure had positive effects on growth and yield of water melon and this could be due to the fact that it contained essential nutrient elements associated with high photosynthetic activities and thus promoted roots, vegetative growth and yield (John *et al.*, 2004). Dauda *et al*. (2008) reported that poultry manure promotes vigorous growth, increases meristematic and physiological activities in the plant due to supply of plant nutrient and improvement in soil properties. These often result in the synthesis of more photo assimilates which are used in producing fruits. According to Khalid (2010) plant height, leaf area index and yield increased with increased poultry manure application. Hui *et al*, (2000) also reported that the effect of poultry manure on fruit sugars, acids and vitamin C, shows that the ratio of sugars to organic acids was higher in fruit with the chicken manure treatment, resulting in a sweeter taste of fruit . There results stated that organic fertilization improved fruit quality revealed by sugar, organic acid and vitamin C concentrations. According to Radzevičius *et al* (2013), tomatoes are a good source of vitamin C, but its content defer greatly due to many factors, but the most influenced ones are growing condition, variety and the environment. Cultural practices such as nutrient application are claimed to be factors influencing quality of tomato before and after harvest (Watkins and Pritts, 2001). According to Nyamah *et al* (2011) in their studies on different soil amendments reported that the best general appearance of fruits were observed in fruits harvested from poultry manure amended fields than those from Control and NPK plus Sulphate of Ammonia fields. According to them, this could be attributed to adequate calcium and magnesium levels which has the ability to reduce defects such as shoulder cracks, increase fruit firmness and to increase overall fruit quality respectively. According to them, the highest firmness was recorded in fruits harvested from fields amended with NPK plus ‘Asasewura’ cocoa fertilizer (3.31N) followed by Control (3.11N), Poultry manure (2.91N) and NPK plus Sulphate of Ammonia (2.80N) amended fields. Their result also revealed that relatively high total soluble solids were recorded for fruits harvested from NPK plus ‘Asasewura’ cocoa fertilizer (4.04% Brix) and Poultry manure (4.02% Brix) amended fields while relatively low total soluble solids were recorded for fruits harvested from fields amended with NPK plus Sulphate of Ammonia (3.91% Brix) and Control (3.42% Brix) (Nyamah *et al*, 2011). Increased in total soluble solid of fruits harvested from fields amended with Poultry manure, over fruits harvested from control and NPK plus Sulphate of Ammonia fields may be as a result of probably higher biosynthesis or degradation of polysaccharides during storage in fruits harvested from fields amended with Poultry manure. Nyamah *et al* (2011) further revealed that fruits harvested from poultry manure amended fields recorded the highest moisture content (92.93%) followed by those from NPK plus Sulphate of Ammonia amended fields (91.05%), followed by Control (90.96%) and NPK plus ‘Asasewura’ cocoa fertilizer amended fields (90.46%) respectively. The relatively high dry matter in fruits harvested from fields amended with various fertilizers NPK plus Sulphate of Ammonia (0.32 g), Poultry manure (0.29 g) and NPK plus ‘Asasewura’ cocoa fertilizer (0.33 g) than fruits harvested from control (0.25 g) fields may be mainly due to the additional plant nutrients for plant utilization supplied by the fertilizers (Nyamah *et al*, 2011). The fruits harvested from fields amended with NPK plus ‘Asasewura’ cocoa fertilizer recorded the lowest weight loss (2.68 g) among fruits from fields amended with NPK plus Sulphate of Ammonia (3.44 g), Poultry manure (3.36 g) and Control (3.07 g) fields (Nyamah *et al*, 2011). Probably, the readily available calcium levels in NPK plus ‘Asasewura’, cocoa fertilize amended fields might have caused relatively low loss of membrane integrity resulting from membrane damage. This could have caused the lowest weight (water) loss rate which might have also led to low membrane ion leakage of fruits harvested from fields amended with NPK plus 'Asasewura', cocoa fertilizer (12.52%) than those from fields amended with Poultry manure (14.61%), NPK plus Sulphate Ammonia (13.87%) and Control (14.61%) respectively. Nyamah *et al* (2011) observed that fruits harvested from NPK plus 'Asasewura' cocoa fertilizer amended fields recorded the highest shelf life (9.39 days) followed by fruits harvested from fields amended with Poultry manure (8.32 days), NPK plus Sulphate of Ammonia (7.92 days) and Control (7.58 days) fields.

2.6 Effects of planting date

In most tropical areas, greater yields are usually associated with early planting and sowing. Early planting has been shown to increase yields in maize (Van Eijnatten, 1960; Lal, 1973), cowpea (Enyi, 1971a) and cassava (Enyi, 1971b). Since the current sowing date for tomato stands the risk of uncertain rains in mid-April, it may be better to delay sowing till the end of April or early May and then sow directly into the field. Tomato grown successfully on open fields vary from 52 South and 54 North latitudes, and also grown under controlled conditions in green houses (Villareal, 1980). On the other hand, there is increasing evidence that the uses of poor cultural practices (especially the practice of wider spacing) as well as traditional cultivars and sowing date are the main yield limiting factors. Presumably, the adoption of high population densities by farmers meant the avoidance of a climate risk. Yet, the improvement of yield through manipulation of plant density and use of early maturing cultivars and optimum sowing date is possible (Abdalbagi *et al*., 2010).

2.7 Post harvest qualities of fruits

Harvested fruits are living organs and even though they are detached from the parent plant, they continue to exchange gas within and loose water to the environment. Since the connection with mother has been cut, the respiratory substrate and water loses that occur cause permanent changes in fruit composition (Brudon,1997)

Many pre-harvest and postharvest factors such as genetics, cultural practices, maturity at harvest and postharvest handling techniques influence composition and quality of fruit by the time it reaches the consumer. However in contrast to pre-harvest factors , postharvest treatment cannot improve the fruit quality above that of a fruit ripened on a plant, but rather slow down the deterioration rate (Brudon, 1997; Kader, 2002) This is true for both climacteric and non-climacteric fruits. Generally the higher the respiration rate of a fruit, the shorter the postharvest shelf life (Kader 2002). Once harvested, keeping fruits within their optimal range of temperature and relative humidity is the most important factor in maintaining fruit quality and minimizing postharvest lost (Kader, 2002; Crisosto *et al.,* 1995)

Maturity at harvest is the factor that mostly influences the final quality of fruits and fruit storage life. Fruit harvested immature are more subjected to shrivelling and mechanical damage than when they are ripe (Kader, 2002; Crisosto *et al.*, 1995). On the other hand, the over ripe has very short shelf life and became too soft. Generally fruit picked too early or too late are more likely to develop physiological disorders and have shorter storage life than harvested mature (Reid,2002).

2.8 Post harvest qualities of fruit at harvest

2.8.1 Fruit firmness

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

2.8.2 Total Soluble Solids

Fruits contain many compounds which are soluble in water example, sugars, acids, vitamin C, amino acids and some pectin. These soluble compounds form the soluble solids content of the fruit. In most ripe fruits, sugars form the main component of total soluble solids. Total soluble solids is an important postharvest quality attribute in screening of new hybrids of fruits. A higher amount of fruit total soluble solids is of major economic value for the processing tomato industry, since even a small increase can significantly enhance yield and decrease the cost of dehydration of puree into sauce and paste (Radzevičius *et al*. (2013). In terms of the amount of the water soluble portion of fruit dry matter, about half is in the form of the fructose (25%) and glucose (22%). A further quarter of the dry matter consists of citric acid (9%), malic acid (4%), amino acids (2%), lipids (2%) and minerals (Radzevičius *et al*., 2013).

2.8.3 pH and Titratable Acidity (TTA) pH values give measure of alkalinity or acidity of a product, whiles the titratable acidity gives a measure of the amount of acid present. Assessment of pH and titratable acidity of fruits are used primarily to estimate consumption quality hidden attributes. Acids make an important contribution to post harvest quality of the fruit, as the test is a balance between sugars and acid content. According to Radzevičius *et al*. (2013), tomato with higher fruit acid and sugar content are most preferred by processors and consumers, but most cultural practices and breeding impact negatively on this trait.

2.8.4 Moisture and Dry Matter Content

Moisture and dry matter content (%) are important postharvest quality criteria since they provide a measure of the water content. They also provide plant breeders with information in determining whether increase yield is due to higher water content or due to genuine increase in harvest weight. For instance in plantain and banana, assessment of dry matter content is essential because the higher the rate of respiration accompanied by water loss that occurs during ripening particularly during climacteric stage causes a net reduction in the proportion of fruit dry matter. Evaluation of dry matter content could provide useful information on the differences in moisture content between hybrids and their parent. High dry matter or low water content of the tomato has also been reported to affect fruit taste positively because the major components of tomato taste; sugars and acids, are more concentrated (Auerswald *et al*., 1999), which fits well with consumers' demand for high quality produce (El-Saeid *et al*., 1996).

2.8.5 Shelf Life Studies

Shelf life is simply the time period that a fruit can be expected to maintain a pre-determined level of quality under specific storage conditions. In other words, the time period (in days) between initiation or commencement of ripening (end of green life) and end of saleable life or edible life of the fruit on the shelf. Increase in weight loss is an indication of increase respiration rate which arises from the breakdown of carbon compounds by metabolism and hence a decrease in fruit shelf life (Nyamah *et al*., 2011).

2.9 Post harvest handling and losses of tomato

The principles that dictate at which stage of maturity a fruit or vegetable should be harvested are crucial to its subsequent storage and marketable life and quality (Mrema and Rolle, 2002). Post-harvest physiologists distinguish three stages in the life span of fruits and vegetables: maturation, ripening, and senescence. Maturation is indicative of the fruit being ready for harvest (FAO, 2008) Harvesting marks the end of the growth cycle of tomatoes and the beginning of a series of stages of very important activities that ensure that the consumer gets the vegetable in the preferred state and at the best of desired quality. Tomato is very perishable because of its high moisture content and this makes it encounter high postharvest losses (Kumah *et al*., 2011). An efficient post-harvest system aims to minimize losses and maintain the quality. Primary factors responsible for post-harvest losses include poor pre-harvest measures, adoption of poor production techniques, non-application of pre-harvest recommended treatments or practices, and post-harvest problems, improper transportation and storage, and distance and time consuming market distribution. These losses bring low return to growers, processors and traders and the country also suffers in terms of foreign exchange earnings (Kader, 2005). Cultural practices such as nutrient application are claimed to be factors influencing quality of tomato before and after harvest (Watkins and Pritts, 2001). The quality and market value of tomatoes depends on the timeliness of harvest and the level of care in handling. Despite the economic and nutritional importance of tomato, very little research has been done to identify the optimum environmental conditions for extending postharvest life of tomatoes (Kumah *et al.,* 2011).

Harvesting fresh-market tomatoes is labour intensive and requires multiple pickings (Orzolek *et. al.,* 2006). They further indicated that tomatoes for the wholesale market should usually be picked at the mature green to breaker stage to prevent the fruit from becoming overripe during long transportation/shipping and handling. They recommend leaving tomatoes on the vine to ripen if they can be brought to market quickly and in good condition and that, it is when market is available that tomatoes should be vine-ripe before harvesting. For the harvesting operation, Kitonoja, and Gorny, (2009). recommends the use of plastic buckets for harvesting fruits that are easily crushed, such as tomatoes. These should be smooth without any sharp edges that could damage the produce. Tomato quality at harvest is primarily based on uniform size and freedom from growth or handling defects. Appearance is a very important quality factor. Good and quality tomatoes should have a waxy gloss; small blossom-end and stem-end scars that are smooth; presence of a brown corky tissue at the stem scar; uniform color; and an absence of growth cracks, sunscald, mechanical injury or bruising. Size is not typically a factor of grade quality, but it may strongly influence commercial buyers' expectations.

Good harvesting management is needed to pick high quality tomatoes. Care must be taken when harvesting "breaker" stage fruit because the riper the tomato, the more susceptible it is to bruising. Harvest crews should carefully place fruits into picking containers instead of dropping them. Research has demonstrated that a drop of more than 6 inches high onto a hard surface can cause internal bruising that is not evident until after the tomato is cut open.

Bruising is characterized by water-soaked cellular breakdown of the cross-wall and locular (seed cavity) area. External bruising will be caused if pickers hurl or dump tomatoes too vigorously from the picking bucket into unpadded bulk bins. Bins should never be overloaded because excessive tomato weight will cause bruise damage due to compression. Harvested tomatoes must be shaded to minimize heat-up. Research has shown that bulk bin tomatoes held in the hot sun for just one hour can be as much as 25^{o}F warmer than fruit held in the shade. Field heat can speed up breakdown after packing. Wet tomatoes should never be harvested, because surface moisture increases field heat accumulations in the load and enhances disease development.

All picking buckets should be cleaned and sanitized at the end of each harvest day to prevent the potential accumulation of disease organisms from infecting sound fruit picked the next production day. Rinse buckets with water to remove soil and field debris, then wash them in a sanitizing solution consisting of 5 oz. of household bleach (5.25 percent sodium hypochlorite) mixed in 5 gallons of water.

Mechanical damage (i.e., cuts, punctures, bruises, scars, scuff marks and discoloured areas) accounts for more defects at the shipping point and in the market than all other defects combined Of these, bruises are the most common and serious, comprising about half of all mechanical damage. Bruised tomatoes may be flattened or indented and soft; the locules either are dry or, if gelatinous tissue is present, it may be thick and stringy from continuous pressure or watery from severe impacts. When tomatoes are physically injured during handling, disease organisms can easily invade the flesh, setting up decay (Ceponis and Butterfield, 1979).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Location of study

The experiment was conducted at the Department of Horticulture, Kwame Nkrumah University of Science and Technology, Kumasi from February 2014 to July 2014.

The site is in the semi-deciduous forest zone with elevation of 186m above sea level (ASL) and has a bimodal rainfall distribution. In the semi-deciduous forest zone, the major rainy season starts in late March and ends in mid-July. There is a short dry spell from mid-July to mid-September followed by the minor rainy season from mid-September to mid-November. The mean annual rainfall is 1500mm. The mean minimum and maximum temperatures are $21^{o}C$ and $31^{o}C$ respectively. The mean annual relative humidity is about 60% at noon and 95% in the morning. The soil at the experimental site is ferric Acrisol (FAO/UNESCO , 1986).

3.2 Scope of study

The study comprised field and laboratory experiments. The field experiment focused on the agronomic performance of the tomato varieties whereas the laboratory experiment centred on the postharvest quality and shelf life characteristics of the tomato varieties.

3.3 FIELD EXPERIMENT

3.4 Experimental design

A 3 x 4 x 3 factorial arrangement in randomized complete block design with four replications was used for the field study. The factors were varieties at three levels: F1 Kaira Hybrid, Pectomech Hybrid and Pectofake (Local); poultry manure at four levels: 0, 2, 4, 6 t/ha; planting dates at three levels: 26th March 2014, 10th April, 2014, 25th April 2014.

Pots were used as plots placed at 5 m x 1 m with an alley 1 m between replications.

3.5 Experimental procedure

3.6 Nursery management

The Pectofacke seeds were obtained from Crops Research Institute-Kwadaso, Pectomech and F1 Kaira were purchased from agrochemical stores in Kumasi. The nursery was carried out in trays in the greenhouse at the Department of Horticulture. Coco peat media was used for raising the nursery. Seeds were sown in the tray at the rate of one seed per hole and slightly covered. They were watered regularly. Seeds were sown to correspond with the three designated planting dates.

3.7 Preparation of pots for planting

Top soil was sieved to remove plant debris, plastic materials and broken glasses. The sieved soil was sterilized using a metal container tray for 30 minutes at 100ºC. The sterilized soil was spread on a large tarpaulin after heating and left covered to cool overnight. The pots were filled with a mixture of sterile topsoil and designated manure level for each planting date. Each pot contained 11 kg of the mixture.

3.8 Crop management

Twenty-two day old seedlings were transplanted into the pots and watered. Watering was done regularly. Compound fertilizer (15-15-15) N-P-K at the rate of 5 g per pot and urea at the rate of 2 g per pot were applied to all the treatments and incorporated into the soil. ACETA STAR, a dual systemic and contact insecticide was applied at a rate of 3ml/l using a knapsack sprayer every two weeks after transplanting to control the observed whiteflies. All the pots were uniformly sprayed to avoid variation between treatments. Weeds were handpicked as and when necessary. The plants were staked at the flowering stage with sticks in all the pots to eliminate lodging and fruit infection by contact with the soil.

3.9 Data Collection

3.9.1 Climatic information

Daily minimum and maximum temperatures, relative humidity, rainfall, solar radiation and wind speed were recorded.

3.9.2 Soil and manure analysis

Samples of the sterilized top soil and poultry manure were analyzed to determine the constituent nutrients and their concentrations.

3.9.3 Number of branches

Number of branches of each treatment was counted at three weeks after transplanting, and the total number of branches recorded as the number of branches for each treatment

3.9.4 Stem girth (cm)

Stem diameter (mm): It was measured using a Vernier-caliber at third node.

3.9.5 Days to flowering

The number of days from emergence to the time of first flower set per treatment was recorded, and their mean was used as days to first flowering for each treatment.

3.9.6 Flower abortion

The number of flowers that dropped from each plant was recorded every day, from the day of flower set, and the total flowers dropped from each treatment were recorded as total flower abortion per plant.

.3.9.7 Plant height at harvest (cm)

The plant height was measured from the soil surface to the apex of the main stem for each treatment/plant.

3.9.8 Number of fruits

The total number of fruits harvested from each plant were counted to determine the number of fruits per plant.

3.9.9 Fruit weight per plant (kg)

The total number of fruits harvested from each plant was weighed with a weighing scale to determine the weight of fruits per plant

3.9.10 total yield(tons/ha) fruits was harvested from pot each and total yield was calculated by the following formula:

Fruit weight (t/ha) Fruit yield (t/ha) = ×10000 divided by harvested pot area

3.9.11 Marketable yield (tons/ha)

After harvest, good quality fruits were selected from the produce and weighed to determine the yield of marketable fruits in tons per hectare.

3.10 POST HARVEST STUDIES

3.11 Preparation of fruits for laboratory analyses

After harvesting, the fruits were removed from the field, sorted and immersed in the cold water to remove field heat. Thirty fruits of good quality for each treatment were selected. Out of the thirty from each treatment, fifteen fruits were used for destructive analytical methods whiles the other fifteen fruits were used for non-destructive methods.

3.12 Experimental design

A 3 x 4 x 3 factorial arrangement in completely randomized design with three replications was used for the postharvest quality analyses in the laboratory. Thirty fruits of good quality for each treatment were selected.

For the shelf life studies, fruits from the best planting date were used and therefore the factors considered were varieties and poultry manure. Consequently, the experimental design was a 3 x 4 factorial arrangement in completely randomized design.

3.13 Data Collection

3.13.1 Fruit firmness (N)

Fruit firmness was determined using the fruit tester, (Effegi type Bishop FT 237). A circular portion of the peel of diameter of about 2cm from each of three fruits from each treatment were removed before applying the plunger of firmness tester in other to avoid the effect due to the peel. Firmness was express in Newton (Batu, 1998).

3.13.2 Pericarp thickness (mm)

The pericarp thickness was determined by cutting the fruit into two, and the flesh inside was measured using the Vernier caliper for each of the three fruits from each treatment.

3.13.3 Dry matter (g)

Dry matter content of fruits was measured by taking three fruit discs of 10 mm in diameter from the equatorial region of each of three fruits and oven dried at 105°C till constant dry weight and recorded in grams (g) (AOAC, 1990).

3.13.4 Moisture content (%)

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

3.13.5 Total soluble solids (% brix)

Total soluble solid was determined using the same three fruits tested for fruit firmness, by squeezing out juice from the fruits onto Abbe's hand held refractometer and reflections measured in percent Brix.

3.13.6 Total titratable acid

Ten ml of fruit juice was diluted with 50ml of distilled water and titrated against 0.1M NaOH. This was repeated three times for each replication and its titre values recorded. The average titre value was calculated for each replication. Total titrable acidity was calculated using the formula;

$$\text{Grams/ litre acid} = \frac{\text{Normality of titrant x titre x Equivalent weight of predominant acid}}{\text{Volume of sample} \times 10}$$

3.13.7 pH Juices was extracted from fruits from each replication and poured into beakers representing the replications. The pH values was determined using the laboratory pH meter. The readings were taken three times for each replication and the average pH for each replication recorded.

3.13.8 Vitamin C concentration (mg/100g)

This was determined by using the 2, 6-Dichloroindophenol Titrimetric method and the results reported as mg/100 g of tomato fruit (AOAC, 1990)

3.13.9 Shelf life (days)

Fifteen fruits from each treatment were monitored for the shelf life studies in the laboratory. The fruits were stored for 14 days at ambient temperature of 26.85°C and relative humidity of 85.75%. The shelf life of the fruits was observed up to the start of rotting of fruits when they were no longer marketable (Mondal, 2000).

3.14 DATA ANALYSIS

The data collected was analyzed by performing an Analysis of Variance (ANOVA) using STATISTX version 9 software. Mean comparisons based on Tukeys (HSD) were carried out to determine significant differences at set probability levels. For the field experiments, P was set at 0.05 (P = 0.05) while for the laboratory studies, P was set at 0.01 (P = 0.01).

CHAPTER FOUR

4.0 RESULTS

4.1. Soil and manure analysis

The soil properties and manure used in the study are presented in Table 4.1. The pH of the soil used was 6.5 which suggested a slightly acidic soil condition. The soil had low content of nitrogen and moderate contents of organic carbon and available phosphorus and Potassium. On the other hand, poultry manure contained high values of organic carbon, nitrogen and potassium.

Table 4.1. The nutrient content of soil and poultry manure used in the study

Sample	Percentage (%)			Available	Exchangeable cations (cmol/kg)				Exchangeable Acidity (cmol/kg)		
	OC	OM	Total N	P(mg/kg)	K	Na	Ca	Mg	Al	H	pH
Soil	1.87	3.22	0.12	27.02	0.42	0.08	9.96	2.38	0.33	0.33	6.5
Manure	11.97	N/A	0.99	1.64	1.41	0.16	2.70	2.84	N/A	N/A	N/A

OC: organic carbon; OM: organic matter; N/A: not available

4.2 Climatic data

The average monthly temperature, relative humidity, solar radiation and rainfall was recorded from March 2014 to May 2014 (Table 4.2). April recorded the highest mean monthly temperature and solar radiation. The highest rainfall and relative humidity were recorded in May whereas no rainfall was recorded in March.

Table 4.2. Climatic data during the period of the experiment (March to May, 2014).

Climatic data	Experimental period		
	March	April	May
Temperature (^{o}C)	33.4	36.6	34.3

Relative Humidity (%)	42	50.1	75.2
Rainfall (mm)	00	5.3	30
Solar radiation	768.3	871	775.8

4.3 GROWTH AND YIELD PARAMETERS OF TOMATO

4.3.1 Number of branches

There were significant variety x planting date interactions for number of branches (Table 4.3). Pectofake planted on 26th March (planting date 1) produced the highest number of branches, significantly greater than those produced by the other varieties at all three planting dates. The least number of branches was produced by Pectomech planted on 15th April (planting date 3) (Table 4.3). Among the varieties, Pectofake produced significantly the highest number of branches. However, the various planting dates resulted in the production of similar number of branches by the tomato plants.

Table 4.3. Effect of varieties and planting dates on the number of branches produced

Varieties	Planting dates			
	26th March	10th April	15th April	Means
F1kaira	15.44	15.875	16.50	16.00
Pectomech	15.81	15.06	15.00	15.13

Pectofake	17.94	16.19	16.31	17.00
Means	16.40	15.71	15.77	
HSD (0.05)	Variety =0.917	Planting date =0.917	Planting date x Variety =1.974	

There were also significant differences in the number of branches produced in terms of the poultry manure applied (Table 4.4). Application of 6 t ha^{-1} of manure resulted in the production of the highest number of branches, significantly greater than the number of branches produced by the applications of 2 t ha^{-1} and 0 t ha^{-1}. The number of branches resulting from the 6 t ha^{-1} application was however similar to those from the 4 t ha^{-1} application (Table 4.4).

Table 4.4. Effect of poultry manure application on number of branches produced

Manure levels (t ha^{-1})	Number of branches per plant
0	14.3
2	15.4
4	17.0
6	18.0
HSD (0.05)	1.13

4.3.2 Number of days to 50 % flowering

There were significant manure x planting date interactions for number of days to 50% flowering (Table 4.5). Plants to which no manure was applied and planted on 10th April, took the longest time (42.3 days) to attain 50% flowering, significantly longer than plants which had 6 t ha^{-1} of poultry manure applied and planted on all three dates (26th March, 10th April and 15th April) which recorded the shortest times (39.9 days; 40.7 days; 40.9 days, respectively) (Table 4.5). Among the manure levels, application of 6 t ha^{-1} led to the plants attaining 50 % flowering in the shortest time though not significantly different from the time taken for plants to which 4 t ha^{-1} had been applied (Table 4.5). Among the planting dates, plants attained 50 % flowering earliest when planted on 10th April though not different from plants planted on 25th April.

Table 4.5. Effect of planting date and manure application on the number of days to 50% flowering.

Manure levels (t ha^{-1})	Planting date			
	26th March	10th April	25th April	Mean
0	41.9	42.3	41.3	41.8
2	41.3	42.1	41.4	41.6
4	40.5	41.3	41.2	41.0
6	39.9	40.7	40.9	40.5
Mean	40.9	41.6	41.2	
HSD (0.05)	Planting date = 0.53 ; Manure = 0.66 ; Planting date x Manure = 1.38			

There were also significant differences in the number of days to 50% flowering for varieties. Both Pectomech (38.3 days) and Pectofake (37.9 days) took the earliest time to attain flowering, significantly different from F1 Kaira (47.5 days) which took the longest time (Table 4.6).

Table 4.6. Effect of variety on the number of days to 50% flowering

Variety	Number of days to 50% flowering

Pectofake	37.9
Pectomech	38.3
F 1 Kaira	47.5
HSD (0.05)	0.53

4.3.3 Number of flowers aborted

Significant manure x planting date and variety x planting date interactions were observed for the number of flowers that were aborted. For the manure x planting date interactions, application of 6 t ha^{-1} of manure to plants planted on all three dates (26th March, 10th April and 25th April) resulted in the least number of flowers aborted, significantly lower than most of the other treatment interactions (Table 4.7). The highest number of flowers aborted was found in plants to which either no manure was applied or 2 t ha^{-1} was applied and planted on 26th March. Among the planting dates, planting on 26th March produced significantly the highest number of flowers aborted. The least were produced similarly by plants planted on 10th and 25th April. Among the manure applications, plants to which no manure (0 t ha^{-1}) was applied produced significantly the highest number of flowers aborted. The number of aborted flowers decreased with increasing manure application and consequently the least number was found in plants to which 6 t ha^{-1} was applied.

Table 4.7. Effect of planting date and manure application on the number of flowers aborted

Manure levels (t ha^{-1})	Planting date			
	26th March	10th April	25th April	Mean

0	16.42	14.00	13.75	14.72
2	14.83	13.17	12.83	13.61
4	13.10	11.92	11.67	12.22
6	11.33	10.83	11.00	11.06
Mean	13.92	12.48	12.31	
HSD (0.05)	Planting date = 0.667	Manure =0.825	Planting date x Manure = 1.731	

For the variety x planting date interactions, Pectofake planted in April (10th and 25th) recorded the least number of aborted flowers, significantly lower than most of the other treatment interactions (Table 4.8). The highest number of flowers aborted was recorded in Pectomech planted on 26th March and on 25th April. F 1 Kaira planted on 25th April also recorded a low number of flowers aborted, similar to that of Pectofake planted on the two April dates. Among the varieties, Pectomech recorded the highest number of flowers aborted, significantly greater than the numbers from F 1 Kaira and Pectofake. The lowest number of flowers aborted was recorded in Pectofake variety. Planting in March led to significantly higher number of aborted flowers than planting in April. (Table 4.8).

Table 4.8. Effect of planting date and variety on the number of flowers aborted

Variety	Planting dates			
	26th March	10th April	25th April	Mean
F 1 Kaira	12.81	12.56	11.69	12.35
Pectomech	15.88	14.44	14.94	15.08
Pectofake	13.06	10.44	10.31	11.27
Mean	13.92	12.48	12.31	
HSD (0.05)	Planting date =0.667 ; Variety =0.667 ;Variety x Planting date =1.435			

4.3.4 Plant height at harvest

There were significant variety x planting date interactions for plant height at harvest (Table 4.9). Pectofake planted on 26th March (planting date 1) produced the tallest plants, significantly greater in height than those produced by the other varieties at all three planting dates. The shortest plants were produced by Pectomech planted on 25th April. Among the varieties, Pectofake produced significantly tallest plants. However, among the planting dates there were no differences in the height of the tomato plants.

Table 4.9. Effect of planting date and variety of plant height at harvest

	Planting date			
Varieties	26th March	10th April	25th April	Mean
F 1 Kaira	71.44	72.94	67.31	70.56
Pectomech	61.81	57.88	52.25	57.31
Pectofake	79.94	72.69	65.81	72.81
Mean	71.06	67.83	61.79	
HSD (0.05)	Planting date =1.393 ; Variety = 1.393 ;Variety x Planting date = 2.998			

There were also significant differences in the height of tomato at harvest due to the poultry manure applied (Table 4.10). Application of 4t/ha and 6 t ha^{-1} of manure resulted in significantly tallest plants at harvest. The height of plants at harvest resulting from the 6 t ha^{1} application was however similar to those produced by the 4 t ha^{-1} application (Table 4.10).

Table 4.10. Effect of poultry manure application on plant height at harvest

Manure Levels (t ha^{-1})	Plant height (cm) at harvest
0	64.4

2	66.0
4	67.8
6	69.4
HSD (0.05)	1.7

4.3.5 Stem girth at harvest

Significant manure x planting date and variety x planting date interactions were observed for the stem girth. For the manure x planting date interactions, application of 6 t ha^{-1} of manure to plants planted on all three dates (26th March, 10th April and 25th April) resulted in the biggest stem girth, significantly larger than most of the other treatment interactions (Table 4.11). The smallest stem girth was found in plants to which either no manure was applied or 2 t ha^{-1} was applied and planted on 26th March. Among the planting dates, planting on 26th March produced significantly the least stem girth. The biggest were produced similarly by plants planted on 10th and 25th April. Among the manure applications, plants to which no manure (0 t ha^{-1}) was applied produced significantly the smallest stem girth. The stem girth increased with increasing manure application and consequently the biggest stem girth was found in plants to which 6 t ha^{-1} was applied (Table 4.11).

Table 4.11: Effect of planting date and poultry manure application on the stem girth

Manure levels (t ha^{-1})	Planting dates			
	26th March	10th April	25th April	Mean
0	1.10	1.23	1.26	1.19

2	1.21	1.25	1.32	1.26
4	1.28	1.33	1.34	1.32
6	1.34	1.38	1.33	1.35
Mean	1.23	1.30	1.31	
HSD (0.05)	Planting date = 0.043 ; Manure = 0.053 ; Planting date x Manure 0.112			

There were also significant differences in stem girth for varieties. Both Pectofake (1.3) and F1 kaira (1.3) had the biggest stem girth, significantly different from Pectomech (1.17) which had the smallest (Table 4.12).

Table 4.12. Effect of variety on stem girth

Variety	stem girth (cm)
F 1 Kaira	1.3
Pectomech	1.2
Pectofake	1.3
HSD (0.05)	0.04

4.3.6 Number of fruits per plant

Significant manure x planting date and variety x planting date interactions were observed for the number of fruits per plant. For the manure x planting date interactions, application of 6 t ha^{-1} of manure to plants planted on all three dates (26th March, 10th April and 25th April) resulted in the highest number of fruits, significantly greater than most of the other treatment interactions (Table 4.13). The least number of fruits was found in plants to which either no manure was applied or 2 t ha^{-1} was applied and planted on 10th and 25th April. Among the planting dates, planting on 26th March resulted in plants producing significantly the highest number of fruits. The least were produced by plants planted on 10th and 25th April. Among the manure applications, plants to which no manure (0 t ha^{-1}) was applied produced significantly the least number of fruits. The number of fruits increased with increasing manure application and consequently the highest number was found in plants to which 6 t ha^{-1} was applied (Table 4.13).

Table 4.13. Effect of planting date and poultry manure applied on the number of fruits per plant

Manure levels (t ha^{-1})	Planting date			
	26th March	10th April	25th April	Mean
0	59.83	58.83	55.83	58.17
2	81.67	73.67	64.67	73.33
4	82.67	77.67	67.67	76.00
6	85.67	78.67	74.17	79.50
Mean	77.46	72.21	65.58	
HSD (0.05)	Planting date = 0.514 ; Manure = 0.635 ; Planting date x Manure = 1.334			

There was significant variety x planting date interactions for number of fruits per plant (Table 4.14). Pectofake planted on 26th March produced the highest number of fruits, significantly greater than those produced by the other varieties at all three planting dates. The least number of fruits was produced by Pectomech planted on 25th April. Among the varieties, Pectofake produced significantly the highest number of fruits. However, the various planting dates resulted in the production of similar number of fruits by the tomato plants.

Table 4.14. Effect of planting date and variety on the number of fruits per plant

Variety	Planting date			
	26th March	10th April	25th April	Mean
F 1 Kaira	76.88	71.63	64.25	70.92
Pectomech	67.75	62.50	55.00	61.75
Pectofake	87.75	82.50	77.50	82.58
Mean	77.46	72.21	65.58	
HSD (0.05)	Planting date = 0.514 ; Variety = 0.514 ; Variety x Planting date = 1.106			

4.3.7 Fruit weight per plant

There were significant varieties x planting date interactions for fruit weight (Table 4.15). Pectofake planted on 26th March produced the heaviest fruit weight, significantly greater than those produced by the other varieties at all three planting dates. The least fruit weight was produced by Pectomech planted on 10th April. Among the varieties, Pectofake produced significantly the highest weight of fruits. However, the various planting dates resulted in the production of similar weight of fruits by the tomato plants.

Table 4.15 Effect of planting date and variety on fruit weight per plant

Varieties	Planting date			
	26th March	10th April	25th April	Mean
F 1 Kaira	3.82	2.91	2.08	2.94
Pectomech	1.36	1.27	1.44	1.36
Pectofake	3.29	3.36	2.91	3.19
Mean	2.83	2.51	2.14	

HSD 5%	Variety=0.458	planting date=0.458	planting x variety=0.986

There were significant differences in the weight of fruits produced in terms of the poultry manure applied (Table 4.16). Application of 6 t ha^{-1} of manure resulted in the production of the heaviest fruits, significantly greater than the fruit weight produced by the applications of 2 t ha^{-1} and 0 t ha^{-1}. The fruit weight resulting from the 6 t ha^{-1} application was however similar to those produced by the 4 t ha^{-1} application (Table 4.16).

Table 4.16. Effect of poultry manure applied on the fruit weight per plant

Manure Levels (t ha^{-1})	Fruit weight (kg)
0	2.0
2	2.4
4	2.6
6	3.1
HSD (0.05)	0.57

4.3.8 Total fruit yield

Significant manure x planting date interactions were observed for the total yield (t/ha) (Table 4.17). Plants to which 6 t ha^{-1} of manure was applied and planted on 25th March and 10th April produced the highest yield (t/ha), significantly greater than most of the other treatment interactions, except plants which received 6 t ha^{-1} of manure and planted on 25th April (Table 4.17). The lowest total yield (t/ha) was produced by plants to which no manure was applied and planted on 25th April. This low yield was however similar to those produced by plants to which received no manure and planted on 10th April or 2 t ha^{-1} and planted on 25th April. Among the planting dates, planting on 25th March and 10th April resulted in a significantly higher fruit yield than planting on 25th April. Among the manure applications, the total yield (t/ha) increased with increasing manure application and consequently the highest yield (t/ha) was found in plants to which 6 t ha^{-1} was applied. The least yield was produced by plants to which no manure was applied (Table 4.17)

Table 4.17. Effect of poultry manure application and planting date on the total fruit yield

	Planting date			
Manure levels (t/ha)	25th March	10th April	25th April	Mean
0	43.17	38.33	32.00	37.83
2	47.00	47.33	37.33	43.89
4	55.50	53.67	47.17	52.11
6	67.00	61.50	55.00	61.17
Mean	53.17	50.21	42.88	
HSD 5%	Planting date = 4.781 ; Manure = 6.061 ; Planting date x Manure =13.432			

There were significant differences in the total yield of fruits produced in terms of poultry manure application (Table 4.18). Application of 6 t ha^{-1} of manure resulted in the production of the highest total yield, significantly better than the total yield produced by the applications of 2 t ha^{-1} and 0 tha^{-1}. The total yield resulting from the 6 t ha-1 application was however similar to those produced by the 4 t ha^{-1} application (Table 4.18).

Table 4.18. Effect of poultry manure applied on the total fruit yield

Manure Levels (t/ha)	Total fruit yield (t/ha)
0	37.83
2	43.89
4	52.11
6	61.17
HSD 5%	6.061

4.3.9 Weight of marketable fruits

There were significant variety x planting date interactions for weight of marketable fruits (t/ha) (Table 4.19). Pectofake planted on all three planting dates (25th March, 10th April and 25th April) resulted in the highest weight of marketable fruits (t/ha), significantly greater than those produced by the other treatments, except F1 Kaira planted on 25th March which produced similar weight of marketable fruits (Table 4.19). Among the varieties, Pectofake produced significantly the highest weight of marketable fruits (t/ha) whiles the least was produced by Pectomech. For the planting dates, planting on either 25th March or 10th April produced the highest weight of marketable fruits, significantly greater than that produced on 25th April.

Table 4.19 Effect of variety and planting date on the weight of marketable fruits

Varieties	Planting date			
	25th March	10th April	25th April	Mean
F 1 Kaira	59.00 a	51.19 a	35.06 b	48.42

Pectomech	23.06 b	21.69 b	24.05 b	23.08
Pectofake	59.00 a	59.38 a	51.38 a	56.58
Mean	47.02	44.08	36.98	
HSD 5%	Variety=4.50 ; planting date=4.50 planting x variety=10.36			

There were significant differences in the weight of marketable fruits (t/ha) from the poultry manure applications (Table 4.20). Application of 6 t ha^{-1} of manure resulted in the highest weight of marketable fruits (t/ha), significantly greater than the weight of marketable fruits (t/ha) produced by the applications of 2 t ha^{-1} and 0 tha^{-1}. The weight of marketable fruits (t/ha) resulting from the 6 t ha-1 application was however similar to those produced by the 4 t ha-1 application (Table 4.20).

Table 4.20. Effect of poultry manure applied on the weight of marketable fruits (t/ha)

Manure Levels (t/ha)	Weight of marketable fruits (t/ha)
0	33.00
2	37.9
4	45.6
6	54.1
HSD (0.05)	5.70

4.4 POST HARVEST QUALITY CHARACTERISTICS

4.4.1 Shelf life of tomato

There were significant varieties x manure interactions for the shelf life of tomato (Table 4.21). The significantly longest fruit shelf life of 14 days was obtained from Pectomech to which 6 t ha^{-1} of poultry manure had been applied. This was however not different from the fruit shelf life of F1 Kaira to which 6 t ha^{-1} of poultry manure had also been applied. The least fruit shelf life of 6.7 days was obtained from both Pectofake and F1 Kaira to which no manure was applied (Table 4.21). Among the varieties, Pectomech fruits had the longest (12 days) shelf life, significantly longer than F1 Kaira fruits (11.2 days) which in turn also had significantly longer shelf life than Pectofake fruits (8.5 days). In terms of the poultry manure, application of 6 t ha^{-1} led to the production of friuts with the longest shelf life, significantly different from those of 4 t ha^{-1} , 2 t ha^{-1} and 0 t ha^{-1} . The least shelf life of fruits was obtained from plants to which no manure was applied (Table 4.21)

Table 4.21. Effect of variety and poultry manure applied on the shelf life of tomato

Manurelevels (t/ha)	Variety			
	F1kaira	Pectomech	Pectofake	Mean
0	6.67c	10.33	6.67 c	8.89
2	10.67bc	11.67 b	8.00 c	10.11
4	11.33b	12.00 b	9.33 c	10.89

6	13.00ab	14.00 a	10.00 c	12.33
Mean	11.17 b	12.00 a	8.50 c	
Hsd at 5%	variety = 0.578	; manure = 0.720 ; variety x manure 1.553		

4.4.2 Titrable Soluble Solids (TSS) and Total Titrable Acidity (TTA)

There were no significant differences between the treatments for both TSS and TTA. TSS ranged between 2.8 and 4.0. On the other hand, TTA ranged from 0.4 to 0.8.

4.4.3 Vitamin C content, pH and moisture

There were no significant differences between the treatments for vitamin C, pH, and moisture content. Vitamin C content of fruits ranged from 11 to 13, pH from 4.73 to 5.23 and moisture content from 93 % to 97 %.

4.4.4. Pericarp thickness, firmness and dry matter

There were no significant differences between the treatments for pericarp thickness, firmness, and dry matter content. Pericarp thickness ranged from 0.4 to 0.6, firmness from 2.7 to 5.3 and dry matter content from 3 % to 7 %.

4.5 RELATIONSHIP ANALYSIS OF POSTHARVEST QUALITY PARAMETERS

4.5.1 Correlation relationships among some quality parameters

There were very strong positive and significant correlations among shelf life and the following parameters; TSS (0.75), TTA (0.86), pericarp thickness (0.85), fruit dry matter content (0.85) and fruit vitamin C content (0.85) (Table 4.22). There were also strong positive and significant correlations among fruit dry matter content and the following parameters ; TTA (0.67), pericarp thickness (0.63). Dry matter also correlated significantly with TSS (0.47) and vitamin C content (0.58) although the associations were of average strength (Table 4.22).

On the other hand, there was a strong negative and significant correlation among shelf life and fruit moisture content (- 0.88). However, there were low and no significant correlations among shelf life and firmness (0.15) and pericarp thickness and firmness (0.15) (Table 4.22).

Table 4.22 Correlation relationships among some postharvest quality parameters of tomato

Correlation variables	Correlation coefficient (r)	Probability level
Shelf life and TSS	0.75	0.000
Shelf life and TTA	0.86	0.000
Shelf life and Pericarp thickness	0.85	0.000
Shelf life and Dry matter	0.85	0.000
Shelf life and Moisture	- 0.88	0.000
Shelf life and Vitamin C	0.85	0.000
TSS and TTA	0.67	0.000
TSS and Moisture	- 0.17	0.047
TTA and Moisture	- 0.21	0.013
TTA and Vitamin C	0.77	0.000
Dry matter and TSS	0.47	0.000
Dry matter and TTA	0.67	0.000
Dry matter and Pericarp thickness	0.63	0.000

Dry matter and Vitamin C	0.58	0.000

4.5.2 Regression relationship between some quality parameters

There was a significant negative effect of poultry manure application on fruit rot of tomato such that as manure application increased, there was a decrease in the extent of rot on the fruits (Eqn 1). Manure application accounted for 62 % of the variation in the fruit rot of tomato (Eqn 1).

$Y_{rot} = 0.3667 - 0.0600X_{(manure)}$; $P = 0.000$; $R^2 = 0.62$; $n = 36$. ……………….Eqn 1.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Plant growth performance of tomato varieties as influenced by poultry manure and planting dates

The addition of poultry manure had a positive effect on the growth of the three tomato varieties. The plant height, number of branches and stem girth all increased as the amount of poultry manure application increased. This is because poultry manure is an excellent source of nitrogen (N), phosphorus (P), potassium (K) and sulfur (S) (Anonymous, 2008) which promotes good growth of plants (Ewulo, 2005). In the present study, the poultry manure might have led to the released nutrients in such high quantities that resulted in the vigorous growth of the tomato plants. Tomato has been reported to respond well to a relatively high level of organic materials (Erenstein *et al*. 2005). John *et al*. (2004) also reported that poultry manure contains essential nutrient elements which are associated with high photosynthetic activities and subsequently promotes plant vegetative growth. Furthermore, Dauda *et al*. (2008) indicated that poultry manure promotes vigorous growth by increasing the meristematic and physiological activities in the plant through from the supply of plant nutrients and improvement in soil properties. In the present study, the pH of the soils of the experimental area (6.5) might have also contributed to the good vegetative growth observed since it is considered as the suitable pH for tomato growth (Peet, 2001). The decline in plant height with delay in planting, in the present study, might be associated with reduced total solar radiation reaching the crop since light intensity has been shown to affect the net assimilation rate of crops (Blackman & Wilson, 1951). Planting late on 25th April may have subjected the plants to cloudy weather associated with the heavy rains experienced in May and June of the experimental year resulting in the slowing down of plant vegetative growth. Similar findings were made by Adelana (1974) in an evaluation of the effects of planting date on the growth and yield of tomato.

5.2 Flowering and yield performance of tomato varieties as influenced by poultry manure and planting dates

The application of poultry manure resulted in early flowering and the number of days to flowering decreased as the quantity of manure applied increased. Similarly, the number of flowers aborted decreased with increasing poultry manure application. Flower abortion of the three tomato varieties varied from 15 to 11 to flowers as the poultry manure application increased from at 0 t/ha to 6 t/ha. This could be attribute to the nutrient status of the soil since the rate of flower abortion in tomato is very related to the nutrient content of the growing medium Ozores *et al*, (2013). Consequently, the higher the poultry manure content, the lower the extent of flower abortion. The time of planting has also been reported to affect the rate of flower abortion such that if humidity is either too high or too low, it interferes with the release of pollen and its ability to stick to the stigma. and therefore may result in flower loss

(Rabinowitch *et al*, 2010). The ideal humidity range for flower retention and fertilisation is between 40 and 70% (Rabinowitch *et al*, 2010). In the present study, the early planting of 26th March resulted in flowering occurring in May when the humidity was very high (80.2 %) resulting in a highest flower abortion observed rate. Ozores *et al*, (2013) also stated that so many factors are associated with flower abortion, among them are high or low relative humidity and solar radiation.

With respect to the varieties, Pectomech recorded the highest number of flowers aborted followed by F1 Kaira with the least from Pectofake. The differential adaptation of the varieties to the environment might account for the observations made since Pectomech and F1 Kaira are hybrids whiles Pectofake is a local variety well adapted to the environment.

Addition of poultry manure had increased tomato yield by 16.0 %, 37.8 % and 61.7 % for 2, 4 and 6 tons/ ha respectively, over no manure application. This suggests that the higher the amount of application of manure the more the nutrients that are released for the growth and yield of the tomato plants. The significantly high yields obtained in the present study could be attributed to the nutrient content of poultry manure which was translated into high vegetative growth giving rise to high photosynthesis which transformed into the high yield. This could be attributed to the high percentage of nitrogen and phosphorus contained in poultry manure which is necessary good growth and yield of plants (Ewulo, 2005; IFA, 2000; Alteri and Nicholls, 1990; Phelam *et al.*, 1995). John *et al.* (2004) also reported that poultry manure had positive effects on growth and yield of water melon which they reported could be due to the fact that poultry manure contained essential nutrient elements that favoured high photosynthetic activities and better translocation of photosynthesis from source to sink. The application of organic manure has been observed to consistently increase the yields of crops such as chilli pepper (Aliyu, 2000) maize (Lombin and Abdullahi, (1997) and sorghum (Agbede *et al.*, 2008).

Planting of tomato on the 26th march at 6 tons/ ha of poultry manure resulted in highest fruit yield/ha. The yield of the tomato decreased with delay in planting date such that the percentage decrease in yield was 5.6 % and 19.4 % as planting was for 2 weeks (10th April) and 4 weeks (25th April), respectively. These results were in agreement with the finding of Abdalbagi *et al* (2010) who reported that the earliest sowing date resulted in a significantly higher total fruit yield compared to the later sowing date and attributed it to better availability of nutrients and better translocation of photosynthates from source to sink. In most tropical areas, greater yields are usually associated with early planting and sowing. Early planting has been shown to increase yields in maize (Van Eijnatten, 1960; Lal, 1973), cowpea (Enyi, 1971a) and cassava (Enyi, 1971b).

Pectofacke, the local variety, produced the highest weight of fruit irrespective of the planting date. This may be due to its efficiency in translocation and partitioning of assimilates from source to sink (fruit).

5.3 Post harvest quality characteristics of tomato varieties

Pectomech had the longest fruit shelf life (12 days) whiles Pectofacke, the local variety, had the shortest fruit shelf life (7.5days). Furthermore, the effect of adding poultry manure was clearly seen on the shelf life of the tomato varieties. Pectomech with 6 tons/ha had the longest fruit shelf life (14days) whereas Pectofake without manure had the shortest fruit shelf life (7days). Nyamah *et al*., 2011) indicated that a decrease in fruit shelf is as a result of an increase in respiration rate which arises from the breakdown of carbon compounds by metabolism.

Poultry manure also affected fruit quality by influencing fruit sugars, acids and vitamin C (Hui *et al*, (2000). In the present study, several strong positive and significant correlations were found among shelf life and some parameters (TSS (0.75, TTA (0.86), pericarp thickness (0.85), dry matter (0.85), Vitamin C (0.85) as well as among dry matter and some parameters (TSS (0.47), TTA (0.67), pericarp thickness (0.63), Vitamin C (0.58)).

Radzevičius *et al*. (2013) indicated that a higher amount of fruit total soluble solids is of a major economic value for the processing tomato industry, since even a small increase can significantly enhance yield and decrease the cost of dehydration of puree into sauce and paste. Titratable acidity of fruits also make an important contribution to post harvest quality of the fruit, as the test is a balance between sugars and acid content. According to Radzevičius *et al*. (2013), tomato with higher fruit acid and sugar content are most preferred by processors and consumers.

High dry matter or low water content of the tomato has also been reported to affect fruit taste positively because the major components of tomato taste; sugars and acids, are more concentrated (Auerswald *et al*., 1999), and fits well with consumers' demand for high quality produce (El-Saeid *et al*., 1996).

In the present study, there was a strong relationship between manure applied and fruit rot such that an increase in manure application resulted in a decrease in fruit rot. This could be attributed to the high nitrogen content of the manure since a decrease in most bacterial diseases including rot has been associated with an increase in nitrogen supply to the fruit (Patriquin *et al*., 1995).

CHAPTER SIX

6.0 CONCLUSION

6.1 Conclusions

The following conclusions could be drawn from the series of experiments undertaken in this study.

Application of 6 tons/ha of poultry manure resulted in the best plant growth in terms of plant height, stem girth and number of branches in the tomato varieties. Irrespective of the time of planting, application of 6 t ha^{-1} of manure resulted in the least number of flowers aborted. Pectofake variety planted in April recorded the lowest number of flowers aborted. Pectofake planted on 26th March produced the highest number of fruits as well as the heaviest fruit weight per plant. The highest total yield of tomato was produced by plants planted in either late March or early April and to which 6 tons/ha had been applied. Pectofake variety produced the greatest weight of marketable fruits, irrespective of the time planted. Application of 6 tons/ha of poultry manure to Pectomech resulted in the longest shelf life of the fruits. Pectomech fruits had the longest shelf life whiles Pectofake fruits had the least. Application of 6 t /ha of poultry manure led to the production of fruits with the longest shelf life. Positive strong and significant correlations existed among shelf life and some fruit quality parameters such as TSS, TTA, Pericarp thickness, dry matter content and Vitamin C content. Positive and strong associations were also found among dry matter of fruits and TSS, TTA and Vitamin C concentration. Conversely, negative strong and significant correlation existed shelf life and fruit moisture content. Manure application accounted for

62 % of the variation in the fruit rot of tomato. Therefore, application of poultry manure at 6tons/ha reduced flower abortion, increased yield and fruit quality of tomato varieties tested than other rates.

6.2 Recommendations for future research

1. Poultry manure and planting times effects on the post harvest qualities of other vegetables should be studied
2. The effects of different soil types and planting times on flower abortion and fruit quality of tomato and other fruit vegetables should also be studied.

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APPENDIX

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Analysis of Variance Table for Daystoflo

Source	DF	SS	MS	F	P
REP	3	1.56	0.52		
Manure	3	39.17	13.06	17.15	0.0000
Variety	2	2860.18	1430.09	1878.30	0.0000
PlantDate	2	11.43	5.72	7.51	0.0009
Manure*Variety	6	4.71	0.78	1.03	0.4097
Manure*PlantDate	6	10.96	1.83	2.40	0.0327
Variety*PlantDate	4	1.78	0.44	0.58	0.6751

Manure*Variety*PlantDate	12	5.17	0.43	0.57	0.8652
Error	105	79.94	0.76		
Total	143	3014.89			

Grand Mean 41.222 CV 2.12

Analysis of Variance Table for Nofruit

Source	DF	SS	MS	F	P
REP	3	33.3	11.11		
Manure	3	9545.0	3181.67	4474.22	0.0000
Variety	2	10466.7	5233.33	7359.38	0.0000
PlantDate	2	3399.5	1699.75	2390.27	0.0000
Manure*Variety	6	68.0	11.33	15.94	0.0000
Manure*PlantDate	6	646.5	107.75	151.52	0.0000
Variety*PlantDate	4	42.3	10.58	14.88	0.0000
Manure*Variety*PlantDate	12	127.0	10.58	14.88	0.0000
Error	105	74.7	0.71		
Total	143	24403.0			

Grand Mean 71.750 CV 1.18

Analysis of Variance Table for WtYLD

Source	DF	SS	MS	F	P
REP	3	0.909	0.3031		
Manure	3	25.189	8.3964	14.87	0.0000
Variety	2	94.207	47.1034	83.40	0.0000
PlantDate	2	11.160	5.5801	9.88	0.0001
Manure*Variety	6	3.329	0.5548	0.98	0.4411
Manure*PlantDate	6	2.017	0.3362	0.60	0.7335
Variety*PlantDate	4	15.159	3.7897	6.71	0.0001
Manure*Variety*PlantDate	12	4.017	0.3348	0.59	0.8438
Error	105	59.306	0.5648		

Total	143	215.293

Grand Mean 2.4931   CV 30.15

Analysis of Variance Table for diseasein

Source	DF	SS	MS	F	P
REP	3	0.187	0.062		
Manure	3	261.743	87.248	272.95	0.0000
Variety	2	73.597	36.799	115.12	0.0000
PlantDate	2	323.556	161.778	506.12	0.0000
Manure*Variety	6	3.903	0.650	2.03	0.0674
Manure*PlantDate	6	23.444	3.907	12.22	0.0000
Variety*PlantDate	4	0.444	0.111	0.35	0.8452
Manure*Variety*PlantDate	12	8.222	0.685	2.14	0.0199
Error	105	33.562	0.320		
Total	143	728.660			

Grand Mean 6.1736   CV 9.16

Analysis of Variance Table for pestinfes

Source	DF	SS	MS	F	P
REP	3	8.333	2.778		
Manure	3	238.000	79.333	375.79	0.0000
Variety	2	42.000	21.000	99.47	0.0000
PlantDate	2	327.875	163.937	776.55	0.0000
Manure*Variety	6	4.667	0.778	3.68	0.0023
Manure*PlantDate	6	34.625	5.771	27.34	0.0000
Variety*PlantDate	4	0.750	0.187	0.89	0.4738
Manure*Variety*PlantDate	12	9.583	0.799	3.78	0.0001
Error	105	22.167	0.211		
Total	143	688.000			

Grand Mean 6.3333   CV 7.25

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Analysis of Variance Table for FLWaborte

Source	DF	SS	MS	F	P
REP	3	0.250	0.083		
Manure	3	276.750	92.250	77.03	0.0000
Variety	2	370.514	185.257	154.69	0.0000
PlantDate	2	74.681	37.340	31.18	0.0000
Manure*Variety	6	3.042	0.507	0.42	0.8620
Manure*PlantDate	6	20.208	3.368	2.81	0.0141
Variety*PlantDate	4	30.694	7.674	6.41	0.0001
Manure*Variety*PlantDate	12	10.750	0.896	0.75	0.7016
Error	105	125.750	1.198		
Total	143	912.639			

Grand Mean 12.903 CV 8.48

Analysis of Variance Table for GirthDia

Source	DF	SS	MS	F	P
REP	3	0.12054	0.04018		
Manure	3	0.51146	0.17049	34.06	0.0000
Variety	2	0.83286	0.41643	83.20	0.0000
PlantDate	2	0.16815	0.08408	16.80	0.0000
Manure*Variety	6	0.01747	0.00291	0.58	0.7442
Manure*PlantDate	6	0.10584	0.01764	3.52	0.0032
Variety*PlantDate	4	0.02739	0.00685	1.37	0.2501
Manure*Variety*PlantDate	12	0.04177	0.00348	0.70	0.7526
Error	105	0.52553	0.00501		
Total	143	2.35102			

Grand Mean 1.2808 CV 5.52

Analysis of Variance Table for NoBranch

Source	DF	SS	MS	F	P
REP	3	13.639	4.5463		
Manure	3	224.917	74.9722	33.10	0.0000
Variety	2	68.375	34.1875	15.09	0.0000
PlantDate	2	13.875	6.9375	3.06	0.0510
Manure*Variety	6	2.625	0.4375	0.19	0.9781
Manure*PlantDate	6	18.125	3.0208	1.33	0.2489
Variety*PlantDate	4	39.625	9.9063	4.37	0.0026
Manure*Variety*PlantDate	12	8.708	0.7257	0.32	0.9843
Error	105	237.861	2.2653		
Total	143	627.750			

Grand Mean 15.958 CV 9.43

Analysis of Variance Table for PlantHt

Source	DF	SS	MS	F	P
REP	3	79.1	26.36		
Manure	3	495.6	165.21	31.62	0.0000
Variety	2	6734.0	3367.00	644.34	0.0000
PlantDate	2	2126.0	1063.02	203.43	0.0000
Manure*Variety	6	19.2	3.20	0.61	0.7194
Manure*PlantDate	6	14.3	2.39	0.46	0.8381
Variety*PlantDate	4	481.1	120.27	23.02	0.0000
Manure*Variety*PlantDate	12	17.4	1.45	0.28	0.9917
Error	105	548.7	5.23		
Total	143	10515.4			

Grand Mean 66.896 CV 3.42

Statistix 9.1 4/8/2015, 7:58:01 AM

Statistix 9.1 4/8/2015, 8:02:29 AM

Analysis of Variance Table for totalyld

Source	DF	SS	MS	F	P
Variety	2	35207.2	17603.6	181.31	0.0000
Manure	3	11097.9	3699.3	38.10	0.0000
Plant	2	2695.2	1347.6	13.88	0.0000
Variety*Manure	6	535.9	89.3	0.92	0.4836
Variety*Plant	4	3245.7	811.4	8.36	0.0000
Manure*Plant	6	157.9	26.3	0.27	0.9493
Variety*Manure*Plant	12	709.2	59.1	0.61	0.8308
Error	108	10486.0	97.1		
Total	143	64135.0			

Grand Mean 48.750 CV 20.21

Analysis of Variance Table for Marketyie

Source	DF	SS	MS	F	P
Variety	2	29291.6	14645.8	170.78	0.0000
Manure	3	9265.9	3088.6	36.02	0.0000
Plant	2	2558.9	1279.5	14.92	0.0000
Variety*Manure	6	605.4	100.9	1.18	0.3243
Variety*Plant	4	2924.8	731.2	8.53	0.0000
Manure*Plant	6	149.2	24.9	0.29	0.9406
Variety*Manure*Plant	12	548.7	45.7	0.53	0.8888
Error	108	9262.0	85.8		
Total	143	54606.6			

Grand Mean 42.694 CV 21.69

Analysis of Variance Table for disease

Source	DF	SS	MS	F	P
Variety	2	20.8472	10.4236	150.10	0.0000
Manure	3	30.1389	10.0463	144.67	0.0000

Plant	2	4.7639	2.3819	34.30	0.0000
Variety*Manure	6	2.9861	0.4977	7.17	0.0000
Variety*Plant	4	1.8194	0.4549	6.55	0.0001
Manure*Plant	6	1.5694	0.2616	3.77	0.0019
Variety*Manure*Plant	12	3.6806	0.3067	4.42	0.0000
Error	108	7.5000	0.0694		
Total	143	73.3056			

Grand Mean 1.6806 CV 15.68

Analysis of Variance Table for TSS

Source DF SS MS F P variety

2 0.43556 0.21778 8.5E+29 0.0000 manure 3

7.45222 2.48407 9.7E+30 0.0000 plantingd 2

1.13556 0.56778 2.2E+30 0.0000 variety*manure 6

9.37778 1.56296 6.1E+30 0.0000 variety*plantingd 4

2.95111 0.73778 2.9E+30 0.0000 manure*plantingd 6

2.41111 0.40185 1.6E+30 0.0000 variety*manure*plantingd 12

37.0489 3.08741 1.2E+31 0.0000

Error 108 2.764E-29 2.559E-31

Total 143 60.8122

Grand Mean 3.4861

WARNING: The model error mean square is too small to continue.

The model may fit the data exactly.

Analysis of Variance Table for pH

Source DF SS MS F P variety

2 3.010 1.50512 1.73 0.1820 manure 3

4.426 1.47550 1.70 0.1721 plantingd 2 0.010

0.00520 0.01 0.9940 variety*manure 6 3.936

0.65603 0.75 0.6073 variety*plantingd 4 1.364

0.34107 0.39 0.8139 manure*plantingd 6 0.736

0.12273 0.14 0.9904 variety*manure*plantingd 12 5.208

0.43398 0.50 0.9113

Error 108 93.924 0.86967

Total 143 112.616

Grand Mean 4.1869 CV 22.27

Analysis of Variance Table for TTA

Source DF SS MS F P variety

2 9.244E-31 4.622E-31 30.36 0.0000 manure 3

0.04778 0.01593 1.0E+30 0.0000 plantingd 2

0.14000 0.07000 4.6E+30 0.0000 variety*manure 6

0.38222 0.06370 4.2E+30 0.0000 variety*plantingd 4

2.465E-32 6.163E-33 0.40 0.8048 manure*plantingd 6

0.21556 0.03593 2.4E+30 0.0000 variety*manure*plantingd 12

1.72444 0.14370 9.4E+30 0.0000

Error 108 1.644E-30 1.522E-32

Total 143 2.51000

Grand Mean 0.5917

WARNING: The model error mean square is too small to continue.

The model may fit the data exactly.

Analysis of Variance Table for drymat

Source DF SS MS F P variety

2 0.722 0.36111 0.33 0.7223 manure 3

5.250 1.75000 1.58 0.1981 plantingd 2 5.931

2.96528   2.68   0.0731 variety*manure   6   39.500

6.58333   5.95   0.0000 variety*plantingd   4   0.694

0.17361   0.16   0.9595 manure*plantingd   6   13.792

2.29861   2.08   0.0617 variety*manure*plantingd   12   82.583

6.88194   6.22   0.0000

Error   108   119.500   1.10648

Total   143   267.972

Grand Mean 4.7361   CV 22.21

Analysis of Variance Table for Firm

Source   DF   SS   MS   F   P variety

2   5.26222   2.63111   1.0E+31   0.0000 manure   3

17.2478   5.74926   2.3E+31   0.0000 plantingd   2

2.97556   1.48778   5.8E+30   0.0000 variety*manure   6

10.8622   1.81037   7.1E+30   0.0000 variety*plantingd   4

2.04444   0.51111   2.0E+30   0.0000 manure*plantingd   6

6.96222   1.16037   4.6E+30   0.0000 variety*manure*plantingd   12

25.2978   2.10815   8.3E+30   0.0000

Error   108   2.752E-29   2.548E-31

Total   143   70.6522

Grand Mean 3.1361

WARNING: The model error mean square is too small to continue.

The model may fit the data exactly.

Analysis of Variance Table for moist

Source   DF   SS   MS   F   P variety

2   97.54   48.7708   0.94   0.3933 manure   3

209.85   69.9514   1.35   0.2620 plantingd   2   47.79

23.8958   0.46   0.6317 variety*manure   6   362.96

60.4931   1.17   0.3290 variety*plantingd   4   204.17

51.0417   0.99   0.4188 manure*plantingd   6   224.21

37.3681   0.72   0.6333 variety*manure*plantingd   12   911.17

75.9306   1.47   0.1484

Error   108   5595.25   51.8079

Total   143   7652.94

Grand Mean 94.646   CV 7.60

Analysis of Variance Table for P

Source   DF   SS   MS   F   P variety

2   2.222E-03   1.111E-03   2.7E+29   0.0000 manure   3

0.12889   0.04296   1.1E+31   0.0000 plantingd   2

0.01556   7.778E-03   1.9E+30   0.0000 variety*manure   6

0.15778   0.02630   6.4E+30   0.0000 variety*plantingd   4

0.08444   0.02111   5.2E+30   0.0000 manure*plantingd   6

0.11778   0.01963   4.8E+30   0.0000 variety*manure*plantingd   12

1.03556   0.08630   2.1E+31   0.0000

Error   108   4.415E-31   4.088E-33

Total   143   1.54222

Grand Mean 0.4389

WARNING: The model error mean square is too small to continue.

The model may fit the data exactly.

Analysis of Variance Table for Vit

Source   DF   SS   MS   F   P variety

2   4.207E-28   2.104E-28   24.89   0.0000 manure   3

2.43556   0.81185   9.6E+28   0.0000 plantingd   2

0.14000   0.07000   8.3E+27   0.0000 variety*manure   6

19.4844   3.24741   3.8E+29   0.0000 variety*plantingd   4

1.473E-29 3.681E-30 0.44 0.7827 manure*plantingd 6

11.8511 1.97519 2.3E+29 0.0000 variety*manure*plantingd 12

94.8089 7.90074 9.3E+29 0.0000

Error 108 9.129E-28 8.453E-30

Total 143 128.720

Grand Mean 12.167

WARNING: The model error mean square is too small to continue.

The model may fit the data exactly.

Analysis of Variance Table for shelf

Source	DF	SS	MS	F	P
REP	2	0.222	0.1111		
MANURE	3	56.222	18.7407	92.77	0.0000
VARIETY	2	80.222	40.1111	198.55	0.0000
MANURE*VARIETY	6	1.778	0.2963	1.47	0.2353
Error	22	4.444	0.2020		
Total	35	142.889			

Grand Mean 10.556 CV 4.26