EFFECTS OF VARIOUS FERTILISER MATERIALS ON GROWTH, YIELD AND NUTRITIONAL QUALITY OF THREE TOMATO VARIETIES

by

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DECLARATION

I Mahlatji Maphotle Baatseba hereby declare that this dissertation titled **'Effects of various fertiliser materials on growth, yield and nutritional quality of three tomato varieties'** is my own work and that all the sources that I have used or quoted have been indicated or acknowledged by means of complete references and that this work has not been submitted before for any other degree at any other institution.

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DEDICATION

This Research report paper is dedicated with love to my parents (Kamele Phanuel and Tubake Constance Mahlatji) and brothers who have been my constant source of inspiration and have given me an excellent support. They gave me the drive and discipline to tackle any task with enthusiasm and determination. Without their love and support this project would not have been made possible. And also to the Almighty God who gave me strength.

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- I acknowledge with thanks, the contribution made by DAFF Zero hunger for providing funds for my studies.
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ABSTRACT

Tomato (*Solanum lycopersicum* L.) is one of the most popular and widely consumed vegetable crops all over the world. They play a vital role in human diet and good sources of vitamins and minerals. However, low soil fertility is a major challenge to vegetable crops production for growers in Africa. Soils in the arid and semi-arid regions like South Africa have little nutrient and mineral contents, which adversely affect plant growth and quality. Therefore, the objectives of the study were to determine the effects of sole and combined applications of Effective Microorganisms enriched compost, broiler manure and inorganic (NPK) fertiliser applications, on growth and yield of three tomato varieties and to assess the influence of the applied fertiliser on nutritional composition of three tomato varieties. Field experiments were conducted at Horticultural skill centre, University of Limpopo (Mankweng), and at Mphebatho farm, Apel, Limpopo province, South Africa. The experiment was laid out in a 7 x 3 split-plot design. Recommended amount of organic and inorganic fertilisers was used. The treatments were: control (without fertiliser application), NPK (2:3:4(30) at a rate of 200 N ha^{-1}, 260 P ha^{-1} and 257 K ha^{-1}, applied as N from Urea, P from superphosphate and K from potassium chloride (KCl), mineralised broiler manure (10 000 kg ha^{-1}), ½ NPK + ½ broiler manure rates, EM enriched compost (14 m^3 ha^{-1}), ½ EM compost + ½ NPK rates, and ½ EM compost + ½ broiler manure rates. Three tomato varieties (Floradade, Roma and Moneymaker) seedlings were transplanted using standard spacing of 30 x 60 cm. Chlorophyll contents of leaves, biomass production, plant height, fruit number, stem diameter and branch number were determined after six weeks of transplanting and fortnightly thereafter. The interactions between tomato varieties and fertiliser materials with regard to plant height were not significant ($P \le 0.05$) at both sites (Apel and Mankweng). Average plant height (63.75 cm) obtained in Moneymaker grown in EM compost treatment was significantly highest at Apel, for Floradade (42.25 cm) in broiler manure treatment while that of Roma variety (39.63 cm) was found in ½ EM compost + ½ NPK treatment at 8 WAT. Similar trend was also recorded at 10 WAT. For Mankweng the significantly ($P \le 0.05$) highest average plant height at 8 WAT (66.63 cm) was obtained in Moneymaker grown in ½ broiler manure + ½ NPK treatment for Floradade (45.63 cm) obtained in broiler manure treatment, and 44.50 cm recorded for Roma in broiler manure treatment. Similar trend was also followed at 10 WAT. At

Apel, significantly highest average number of tomato fruits at 8, 10 and 12 WAT were recorded in treatment with ½ EM + ½ NPK while the least values were found in control. Whereas at Mankweng the variation in number of tomato fruits under different fertiliser treatments were not significant. Similar, non-significant interactions (V x F) for tomato shoot nutritional composition were found in tomato grown at both sites (Apel and Mankweng) in relation to fertiliser treatments. At Apel however, comparing the fertiliser treatments, tomato grown in soil treated with ½ broiler manure + ½ NPK had the significantly highest average (3.01 %) K content while the least value (2.65 %) was obtained in the control. Similarly, significantly highest mean (44.33 mg kg^{-1}) Zn was found in crops grown in the same treatment, but the lowest significant value (36.50 mg kg^{-1}) was obtained in ½ EM + ½ NPK treatment. For Mn and Fe contents in tomato significantly highest mean values (150.17 mg kg^{-1} and 2381 mg kg^{-1}) for Mn and Fe respectively were found in sole broiler manure treatment while the least values 114.83 mg kg^{-1} and 1357.6 mg kg^{-1} for Mn and Fe respectively were found in ½ EM + ½ NPK and sole NPK treatments respectively. It may be concluded that in tomato production, combined application of organic and inorganic sources of nutrients can be more beneficial and can be adopted by smallholder farmers with limited resources.

Keywords: broiler manure, effective microorganisms' enriched compost, inorganic fertilisers

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CHAPTER 1

GENERAL INTRODUCTION

1.1 Background

Tomato (*Solanum lycopersicum* L.) is one of the most popular and widely consumed vegetable crops all over the world, and high-quality yield is an essential prerequisite for its economic success in South Africa. Tomato has gained attention in relation to the prevention of some human diseases. This interest was due to the presence of carotenoids and particularly lycopene (Gerster, 1997; Abdel-Monaim, 2012).

Soils in the arid and semi-arid regions like South Africa have little nutrient and mineral contents, which adversely affect plant growth and quality. These soils can act as a limiting factor for the production of tomato plants. Soil fertility is a major over-riding constraint that affects all aspects of crop production (Mbah, 2006). One of the cost-effective strategies for counteracting deficiencies of soil minerals involves the application of chemical fertilisers (Adekiya and Agbede, 2009). Chemical fertiliser was advocated for crop production to ameliorate low inherent fertility of soils. Chemical fertilisers being expensive and scarce, organic fertilisers such as farmyard manure (FYM), poultry manure (PM), compost, among others, had been used for crop production for centuries. The use of these forms of fertilisers certainly pre-date chemical (mineral) fertilisers (Oyewole and Oyewole, 2011).

Poultry manure is an excellent organic fertiliser, as it contains high nitrogen (N), phosphorus (P), potassium (K) and other essential nutrients (Oyewole and Oyewole, 2011). Poultry manure more readily supplies P to plants than other organic manure sources (Garg and Bahla, 2008). Although, poultry manure is an excellent nutrient source for plants, supplementing soil nutrients, require sound soil fertility management practices to prevent nutrient imbalances and associated animal health risks as well as surface - water and ground water contamination (Blay *et al*., 2002). The use of organic manure, e.g. poultry manure and ruminant dung has improved agricultural productivity in Southern African countries. Organic manure helps to improve the physical condition of soil and provides the required plant nutrients (Ngeze, 1998).

The use of Effective Microorganisms composts also contributes significantly to the production of vegetables. It increases the numbers of beneficial microorganisms in soil, thus maintaining the natural ecosystem of the cultivated land and diminishing the risk of environmental pollution with improved crop productivity and quality. Microorganisms enhance the efficacy of farming systems due to their role in decomposition of manures, symbiotic and fermentative processes. Effective Microorganisms increase biological soil activities and improve physical and chemical soil properties through rapid humification of fresh organic matter (Obi and Ebo, 1995).

1.2 Description of the research problem

Tomato is the second most important and popular vegetable crop after potatoes in South Africa. It contributed approximately 18.3% to the gross value of vegetable production in 2015 (DAFF, 2016). Tomatoes play a vital role in human diet and good sources of vitamins and minerals. Tomato crop is not only cultivated commercially but also community grown by subsistence, resource poor farmers and home gardeners. However, low soil fertility is a major challenge to vegetable crops production for growers in Africa (Blay *et al*., 2002). Smallholder farmers in the Limpopo Province experience challenges in terms of limited financial resources, availability, accessibility and lack of knowledge in terms of actual amount of inorganic fertiliser to apply. Assessment of fertiliser options for improved production of this valued crop will be of immense benefit to smallholder farmers in Limpopo Province.

1.3 Motivation of the study

The smallholder farmers in the rural community of Limpopo Province, South Africa grow tomato for food and low soil fertility threatens production. Soil fertility is a major overriding constraint that affects all aspects of crop production. The identified gap for the study is that most research carried out on tomato are based on nutrition. However, little information is known on how organic fertilisers in combination with genotypic variation influences physical and phytochemical contents of tomato fruit. Organic fertiliser is cheaper therefore it will reduce the amount of money spent by farmers as compared to chemical fertilisers. Investigation on alternative sources of fertiliser for tomato production on soils in Limpopo Province will be of utmost benefit to growers. Assessment of the use of varied sources of soil nutrient amendments for tomato production can lead to improved yield, better quality and contribute to food security in the Province.

1.4 Aim and objectives of the study

The aim of this study was to assess growth, yield and nutritional quality of three tomato varieties following integrated broiler manure, EM enriched compost and inorganic NPK fertiliser application.

The specific objectives of the study were to:

i. Determine the effects of sole and combined applications of EM enriched compost, broiler manure and inorganic NPK fertiliser applications, on growth and yield of three tomato varieties.
ii. Assess the influence of the applied fertiliser on nutritional composition of three tomato varieties.

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CHAPTER 2

LITERATURE REVIEW

2.1 Work done on research problem

2.1.1 Origin and domestication of tomato

Tomato is one of the most important protective food vegetable crops in the world because of its special nutritive value and widespread production. The origin and distribution of cultivated tomato originated from Peru, Ecuador, Bolivia. Domesticated place of tomato lies in Mexico (Joubert, 1974). The ancestor of cultivated tomato is cherry type (*Lycopersicon esculenta var cerasiformae* **-** cherry tomato). From Mexico is distributed to European countries. Tomato is indigenous to the Peru and Equador region in South America and it probably evolved from *Lycopersicon esculentum var. cerasiforme*, the cherry form. However, it was domesticated and first cultivated in Central America by early Indian civilisations of Mexico. The Spanish explorers introduced tomato into Spain and it was later taken to Morocco, Turkey and Italy. In Italy and France, it was termed “love apple”. Tomato is now one of the most popular and widely grown vegetables around the world (Farming SA and ARC, 2009).

2.1.2 The growth habit of tomato

The tomato is a perennial plant but usually grown as an annual plant. It is reported that the tomato plant can reach up to 3 meter (Farming SA and ARC, 2009). The stems are somewhat weak and often require staking or support such as a tomato cage. Branching at the base is monopodial, becomes sympodial higher up. The tomato leaves are at-least 10 to 30 cm long and unevenly imparipinnate compound with variously indented or lobed margins. Both the stems and the leaves are slightly rough and fuzzy. The inflorescence of tomato bare small yellow flowers and has five pointed lobes on the corolla. The tomato fruits are fleshy berries, green when unripe and become deep red and shiny when ripe. The tomato cultivars differ a great deal in size, shape and colour. There are yellow, orange, green and brown varieties of fruits. The shape can vary from small cherry tomatoes, pear shaped tomatoes to large irregular shaped beefy tomatoes. The shape, size and colour of tomato decide their market value (Farming SA and ARC, 2009).

2.1.3 Description of tomato varieties

Roma variety: Roma tomatoes are egg or pear-shaped and red when fully ripe. They have few seeds and are a good canning and sauce tomato. While Roma is an open-pollinated variety, in general it is not considered an heirloom tomato. Maturing in under three months, the plant itself grows up to 1 meter (36 inches) in height and the single fruit weighs about 57 grams. They fruit heavily, making Roma a popular variety with gardeners who do a lot of home canning (LISP, 2011).

Floradade variety: Floradade is a variety of tomato which is considered an heirloom OP (open pollinated) cultivar. Floradade grows as an annual crop and it tends to grow best over the course of a single year. Floradade variety is known for growing to a height of approximately 1.20 metres (3.90 feet). Popular market tomato, grows well in hot and humid areas. When the tomato fruit ripe, it appears in these approximate shapes: red globular fruit or deep oblate, firm, with smooth skin (LISP, 2011).

Moneymaker variety: The “Money maker” variety is an indeterminate tomato plant *(Solanum lycopersicum*) which continues to grow all summer, resulting in a long season of plenty of fresh tomatoes. It features medium-sized tomatoes suitable for fresh use and preserves, supplying an ample harvest from each plant. Like most tomatoes, “Money maker” grows as a summer annual crop and requires warm, frost-free weather to produce at its best. The fruits are bright red,deep globe shape, sweet lasting but slightly lacking the deep tomato flavour of some varieties. The skins are average thickness neither thin nor particularly thick (LISP, 2011).

2.1.4 Effect of inorganic fertiliser on growth and yield of tomato

Chemical fertiliser application is mostly used to correct known plant nutrients deficiencies and also to supply high levels of nutrients in order to maintain optimum soil fertility conditions and improve crop growth, quality and yield. According to (Leonard, 1986) chemicals fertilisers are needed to supply the amount of nutrients needed to sustain high yield and to make certain that soil fertility does not limit crop production.

Potassium: According to (Hue, 1995) potassium is major essential element that is required in large amount by many crops for maintain the osmotic potential of cells and turgidity of plant. Potassium play an important role in water up take by plant and also water retention in the plant tissue (Marschner, 1995). Potassium improves plant resistance to water logging, pest and diseases (Bergmann, 1992). Studies suggested that potassium deficient plant has a low resistance to diseases and their fruits are more likely to be small (Perrenoud, 1993).

Nitrogen: Nitrogen is the most vital nutrient and nitrogen become available from decomposition of organic matter which is converted into (N_4H^+) by microorganisms such as bacteria and fungi through the process of mineralization reviewed by (Pidwirmy, 2002). Nitrogen is an essential nutrient for plant growth, chlorophyll and protein formation. Since soil N is mostly organic in nature, N concentrations in soil increase with increased organic matter contents (Camberato, 2001).

Phosphorus: Phosphorus is essential for plant growth and it exists in the soil in both organic and inorganic forms. P concentration in the soil is very variable and may range from zero to more than 2%. Its content increases with increased organic matter content and a positive linear regression exists between organic P and organic C content. Available P is the P in soil that is in a form that can be taken up by plants. The various soil fertility management practices implored have an effect on the available P (Kamanga, 2013).

2.1.5 Effect of organic fertiliser on growth and yield of tomato

Use of organic manures for plant nutrient supply and for beneficial effects on soil physical properties is a traditional agricultural practice. Application of organic fertilisers has been a noble and traditional practice of maintaining soil health and fertility. The use of this organic fertilisers results in higher growth, yield and quality of crops. They contain macro nutrients, essential micro nutrients, many vitamins, growth promoting factors like IAA, GA and beneficial microorganisms (Natarjan, 2007; Sreenivasa *et al.*, 2010). Organic manure contains high levels of relatively available nutrients elements, which are essentially required for plant growth. Moreover, it plays an important role for improving soil physical properties.

Effective microorganisms' (EM) are commercialised as a mineralisation and plant growth promoting product for speeding up the natural composting process without many of the negative side effects of foul odors and pests. Adding EM compost to the soil and then mulching it will help to hold in moisture, requiring less watering, keep weeds down, and provide a home for worms and microbes. If used properly, EM compost can significantly enhance the soil fertility and promotes growth, flowering, fruit development and ripening in crops. It can increase crop yields and improve crop quality as well as accelerating the breakdown of organic matter from crop residues (Abdul *et al*., 2006).

In Agriculture, the effect of long term application of EM compost for soil fertility and crop yield improvement was investigated at China Agricultural University from 1993 to 2013. This filed experiment shows that “the application of EM in combination with compost significantly increased wheat straw biomass, grain yield, straw and grain nutrition compared with traditional compost and control treatment.” Also, the experiment indicates the significant efficacy of EM on organic nutrition sources (Hu and Qi, 2013).

2.1.6 Nutritional qualities of tomato

Tomatoes play a vital role in human diet and are excellent source of vitamins, minerals, and antioxidants which help control cancer, health disease as well as improve the general health of man (Ogundare *et al*., 2015). The fruits are eaten raw or cooked and can be processed into soup, juice, sauce, ketchup, puree, paste and powder. They also serve as an ingredient in stews and vegetable salads. In some cases, especially in Northern Nigeria the fruits are sliced and dried for sale. Tomato fruits contain high amount of ascorbic acid and lycopene. Lycopene, an antioxidant, is the pigment that imparts red color to some fruits, most notably tomato and watermelon. It is also a highly efficient oxygen radical scavenger and has been implicated in human health as providing protection against cardiovascular disease and some cancers, particularly that of the prostate (Ilupeju *et al.,* 2015).

2.2 Work not yet done on research problem

In the past years, inorganic fertiliser was advocated for crop production to ameliorate low inherent fertility of soils in Africa. In addition to being expensive and scarce, the use of inorganic fertiliser has not been helpful in intensive agriculture because it is often associated with reduced crop yield, soil acidity and nutrient imbalance (Ano and Agwu, 2005). The need to use renewable forms of energy and reduce costs of fertilising crops has revived the use of organic fertilisers worldwide (Ayoola and Adeniyan, 2006).

The use of organic fertilisers and EM as soil amendment for crop production has been observed among some commercial farmers in South Africa. The problems associated with the use of hazardous chemicals for crop protection, weed control and soil fertility are receiving increasing attention worldwide since pests, diseases and weeds become resistant to chemical pesticides and environmental pollution and ecological imbalances may occur (Mohammad *et al.,* 2013).

In the recent past, some studies have been conducted to elucidate the beneficial effects of adding crop residue compost into the soil. The practice improves soil physical, chemical and biological activities as well as improving crop yields and nutritional values (Maharishnan *et al.,* 2004). However, the supply of organic materials on farms, even with the use of farm yard manure and compost from crop residues, will likely be insufficient to overcome soil nutrient deficiency. The integration of small amount of inorganic fertiliser with the organic materials available on farms offers a strategy to meet the nutrient requirements of crops (Maharishnan *et al.,* 2004).

Despite many investigations in the area of nutrition, knowledge on how organic fertilisers in combination with genotypic variation influences physical and phytochemical contents of tomato fruit is inadequate. As a result of increased popularity of organic vegetable production, more information is needed comparing the yield and quality of vegetable crops produced organically or using mineral fertiliser. Furthermore, the benefits of using organic materials have not been fully utilized in the arid and semi-arid regions, partly due to the huge quantities required to satisfy the nutritional needs of crops, transportation and handling costs (Ayoola and Adeniyan, 2006).

High and sustained crop yield can be obtained with judicious and balanced NPK fertilisation combined with organic matter amendment. A balanced use of organic and inorganic fertilisers could enhance soil chemical, physical, and biological properties as well as rate of nutrient turn over within the soil plant system (Ayoola and Adeniyan, 2006). Hence, the study is conducted in order to determine growth, yield and nutritional quality of three tomato varieties to sole and combined applications of Effective microorganisms (EM) (Ravivi) enriched composed, broiler manure and inorganic (NPK) fertiliser applications.

CHAPTER 3

METHODOLOGY

3.1 Study sites

Field experiments were conducted at the field next to the Horticultural skill centre (23°53′10″S, 29°44′15″E), University of Limpopo, Mankweng, and at Mphebatho cooperative farm (24°41′56″S, 29°74′26″E), Apel, Limpopo province, South Africa.

The soil at the Horticultural centre is sandy loam while the soil at Apel is moderately well drained with clay textural class (Table 3.1). Mankweng area usually receives mean annual rainfall of 500 mm that is often fairly distributed over the growing period (Table 3.2) and daily temperature range of 12 to 35°C during planting season (Mpangane *et al.,* 2004). Average rainfall recorded was 29.6 mm and minimum and maximum temperatures recorded were 5.35 to 29.35°C respectively.

Table 3.1: Soil analytical results for the experimental sites before planting at Apel and Horticultural centre (Mankweng)

Property	Apel	Horticultural centre (Mankweng)
pH (KCl)	6.82	4.80
N (%)	0.13	0.15
P (mg/L)	2	74
K (mg/L)	99	104
Ca (mg/L)	2879	709
Mg (mg/L)	1983	98
Zn (mg/L)	0.9	16.4
Mn (mg/L)	2	4.3
Cu (mg/L)	3.7	10.9
Organic C (%)	0.7	0.9
Exc. Acidity (cmol/L)	0.10	0.12
Total cations (cmol/L)	31.05	4.73
Acid Sat. (%)	0.13	2.58
Clay (%)	36.56	20.83
Textural class	Clay	Sandy loam

Table 3.2: Monthly rainfall and temperatures from March-June months at Horticultural centre (Mankweng) during 2015 planting season

Month/Year	Rainfall (mm)	Temperature (˚C)	
		Minimum	Maximum
March/2015	15.0	8.1	33.0
April/2015	81.3	8.3	29.4
May/2015	21.1	4.0	29.0
June/2015	1.0	1.0	26.0
Average	29.6	5.35	29.35

Source: University of Limpopo experimental station records

Apel is located in Sekhukhune District, in the summer rainfall zone of the country. It is a semi-arid area where the Southern parts of the area receives more rain (between 600 mm - 800 mm annually), whilst the Northern parts receives only 500 mm - 600 mm annually. The area has average summer temperatures of 23˚C as well as a maximum of 28˚C and a minimum of 18˚C (Table 3.3). In winter, the average is 13.5˚C with the maximum of 20˚C and a minimum of 7˚C (as measured at the Sekhukhune Weather Station). During the duration of the experiment, the average minimum and maximum temperatures were 7.75 and 22.0˚C, respectively, and the average rainfall recorded was 10.1 mm.

Table 3.3: Monthly temperatures from April – July months at Apel during 2015 planting season

Month/Year	Rainfall (mm)	Temperature (˚C)	
		Minimum	Maximum
April/2015	25.4	13.0	25.0
May/2015	10.2	9.0	23.0
June/2015	2.5	5.0	20.0
July/2015	2.5	4.0	20.0
Average	10.1	7.75	22.0

Source: Polokwane weather station

3.2 Land preparation and pre-planting soil sample

Before transplanting and after the final harvest, soil samples from 0-15 and 15-30 cm depths were collected randomly at the experimental site. Soils were mixed and air-dried and ground to pass through a 2-mm sieve and taken for analysis. The chemical and physical properties of the soil were determined (Table 3.1). Nutrients such as nitrogen, phosphorus and potassium and soil pH were determined. The compositions of nutrients were determined as described by AOAC (2005).

3.3 Planting of the trial and sources of planting materials

Establishment at Horticultural centre was during the month of March on the 11th and establishment at Apel was done in April on the 29th 2015.

Seeds were sown in February in the seedling trays filled with hygro-mix at Turfloop campus, shade house and transplanted during March. For the second trial, the seeds were sown in March and transplanted during March. Fresh water was supplied every morning to avoid wilting and for normal plant development. Other seedling management included irrigation with (Multifeed at 1 g/L water) in order to promote growth. Fertiliser materials that were used are Urea, potassium chloride (KCl) and single superphosphate.

3.4 Experimental design, treatments and procedures

The experiment was laid out in a 7 x 3 split-plot design. Fertiliser amendments were assigned to main plots while tomato varieties were placed in subplots. Treatments were replicated four times. The treatments were (1) control (without fertiliser application), (2) recommended amount of inorganic fertiliser NPK (2:3:4(30) at a rate of 200 N, 260 P and 257 K, this was applied as N from Urea, P from superphosphate

and K from potassium chloride (KCl), (3) recommended amount of decomposed broiler manure (10 000 kg ha^{-1}), (4) ½ of recommended amount of inorganic fertiliser + ½ of recommended amount of broiler manure, (5) recommended amount of Effective Microorganisms-enriched compost (14 m^{3} ha^{-1}), (6) ½ of recommended amount of EM-enriched compost + ½ recommended amount of inorganic fertiliser, (7) ½ of recommended amount of EM compost + ½ of recommended amount of broiler manure. Each experimental unit was 2 m x 2 m with 1 m spacing between units and 1 m between blocks. Transplanting of tomato (Floradade, Roma, Moneymaker) seedlings was done using standard spacing of 30 x 60 cm. The inorganic fertiliser application rates were based on soil analysis recommended by Cedara, Em application rate (ZZ2) and broiler manure (ZZ2). Decomposed broiler manure was applied and chemical analysis of broiler manure and EM composed for elements such as C, N, P, K and Mg were determined before application. The field at each trial site was prepared using standard soil preparation techniques. Weeds were controlled using hoes while supplementary irrigation and pest control were carried out at regular intervals as required during the growing period.

(a) (b) (c)

Figure 3.1: Tomato varieties grown at the two sites (Apel and Horticultural centre). a) Roma, b) Moneymaker, c) Floradade

3.5 Data collection

Data collected included stand establishment at two weeks after transplanting and at harvest, this was done by counting number of surviving plants per plot. Plant height was measured from the bottom of the main stem close to the soil to the growing tip of the stem using a string and a measuring tape from six weeks after transplanting (WAT) and fortnightly thereafter. Branch number was counted at six weeks after transplanting and fortnightly thereafter and two data plants were selected per plot. Stem diameter was measured at six weeks after transplanting and fortnightly thereafter using a Vernier calliper. Chlorophyll content was measured using Opti-Science CCM Plus Chlorophyll meter fortnightly from six weeks after transplanting. Number of fruits was counted from six weeks after transplanting and fortnightly thereafter. Fresh and dry weight determination was done eight weeks after transplanting and at final harvest.

At maturity, plant samples were partitioned into shoot, root and fruits. Dry weight was determined after drying in an oven at 80 ^{o}C for 48 hours. At harvest fruit diameter was measured using a Vernier calliper in the laboratory. Furthermore, dried plants samples (shoot) were taken for analyses at Cedara laboratories to determine the chemical composition. At harvest the samples were prepared and analysed according to the standard methods described in the AOAC (2005). The following parameters were determined: Calcium (Ca), Iron (Fe), Potassium (K), Zinc (Zn), Phosphorus (P), Sodium (Na), Magnesium (Mg), Nitrogen (N), Copper (Cu), Aluminium (Al), and Manganese (Mn). The percent protein of plant parts (shoot) were estimated using the relationship: **Crude protein % = N % x 6.25** (Ezeagu *et al.,* 2002).

3.6 Data analysis

All data collected were subjected to analysis of variance (ANOVA), using statistix 9.0 software programme. Means were separated using Tukey HSD at $P \leq 0.05$.

CHAPTER 4

RESULTS AND DISCUSSION

4.1. Effect of EM-enriched compost, inorganic fertiliser and broiler manure on growth of three tomato varieties

Application of fertilisers (organic or inorganic) resulted in increased tomato plant growth. The interactions between tomato varieties and fertiliser materials with regards to plant height were not significant ($P \leq 0.05$) at both sites, that is Apel and Mankweng (Appendices 4.1 and 4.2). The highest average plant height of 63.75 cm was obtained in Moneymaker grown in EM compost treatment at Apel. For Floradade (42.25 cm) in broiler manure treatments while that of Roma variety (39.63 cm) was found in ½ EM compost + ½ NPK treatment at 8 WAT (Figure 4.1). Similar trend was also recorded at 10 WAT (Figure 4.2). For Mankweng, the significantly ($P \leq 0.05$) highest average plant height of 66.63 cm at 8 WAT was obtained in Moneymaker grown in ½ broiler manure + ½ NPK treatment, for Floradade (45.63 cm) was obtained in broiler manure treatment, and 44.50 cm recorded for Roma in broiler manure treatment (Figure 4.3). Similar trend was also followed at 10 WAT (Figure 4.4). The three varieties therefore differ in their responses to the fertiliser treatments. Although consistent response in trend with regards to location, the three varieties still differ in relation to fertiliser treatments. The Moneymaker had the highest average height at both locations, at Apel, the highest average height was obtained in sole EM compost treatment while at Mankweng the highest average height for Moneymaker was found in ½ broiler manure + ½ NPK treatment. These agree with previous findings by Adekiya and Agbede, (2009) who revealed that the vegetative growth attribute such as plant height and yield of tomato was highest with combined application of inorganic NPK fertiliser and broiler manure. The varied vegetative development of these three tomato varieties could be attributed to differences in their genetic make- up. Comparing the tomato varieties Moneymaker had the highest mean height, 51.41 cm (Apel) and 54.88 cm (Mankweng) at 8 WAT (Tables 4.1 and 4.2). Whereas the differences observed in tomato plant height at both locations in relation to fertiliser materials were not significant.

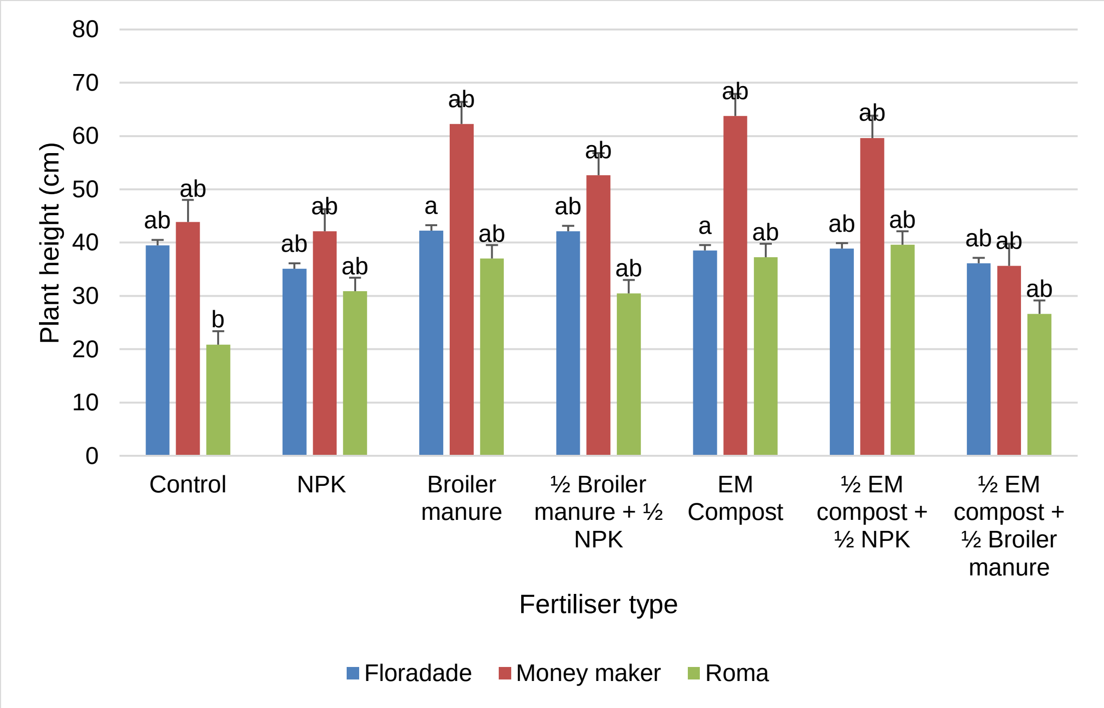

Figure 4.1: Effect of fertiliser application on plant height (cm) of three tomato varieties grown at Apel at 8 WAT

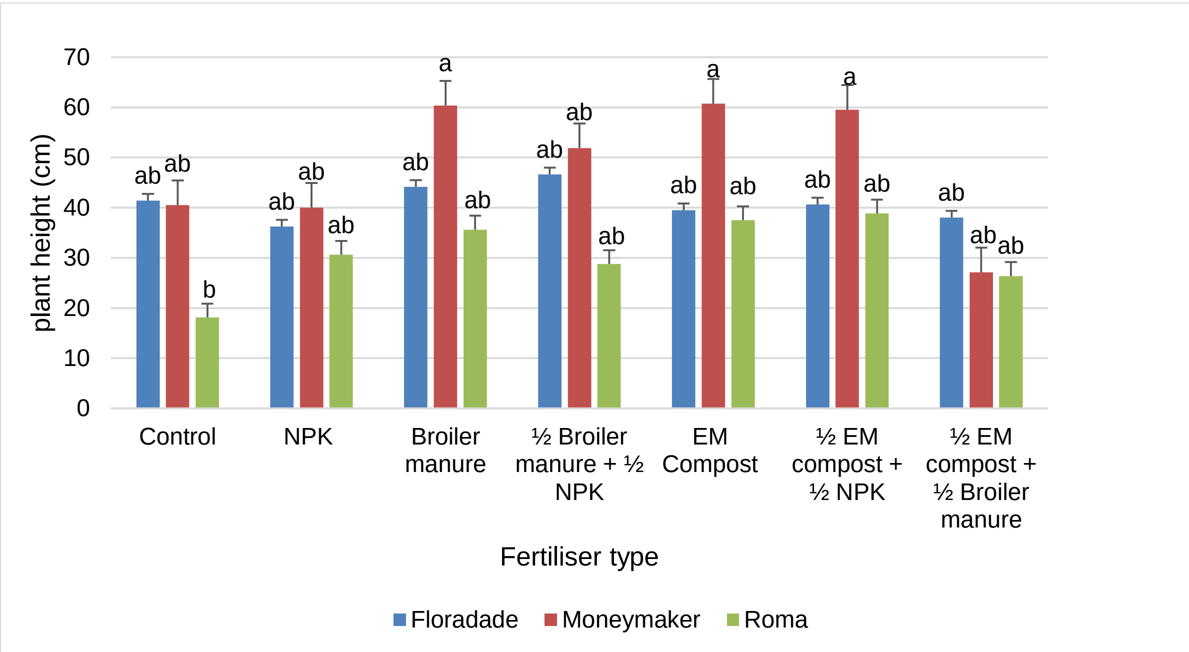

Figure 4.2: Effect of fertiliser application on plant height (cm) of three tomato varieties grown at Apel at 10 WAT

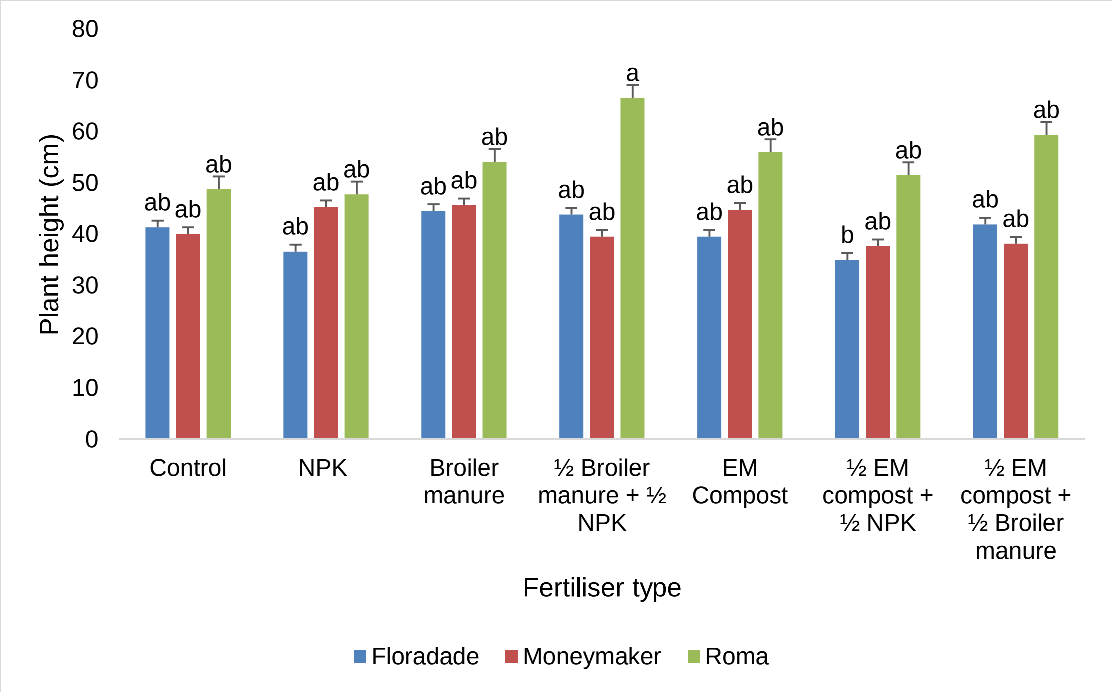

Figure 4.3: Effect of fertiliser application on plant height (cm) of three tomato varieties grown at Horticultural centre (Mankweng) at 8 WAT

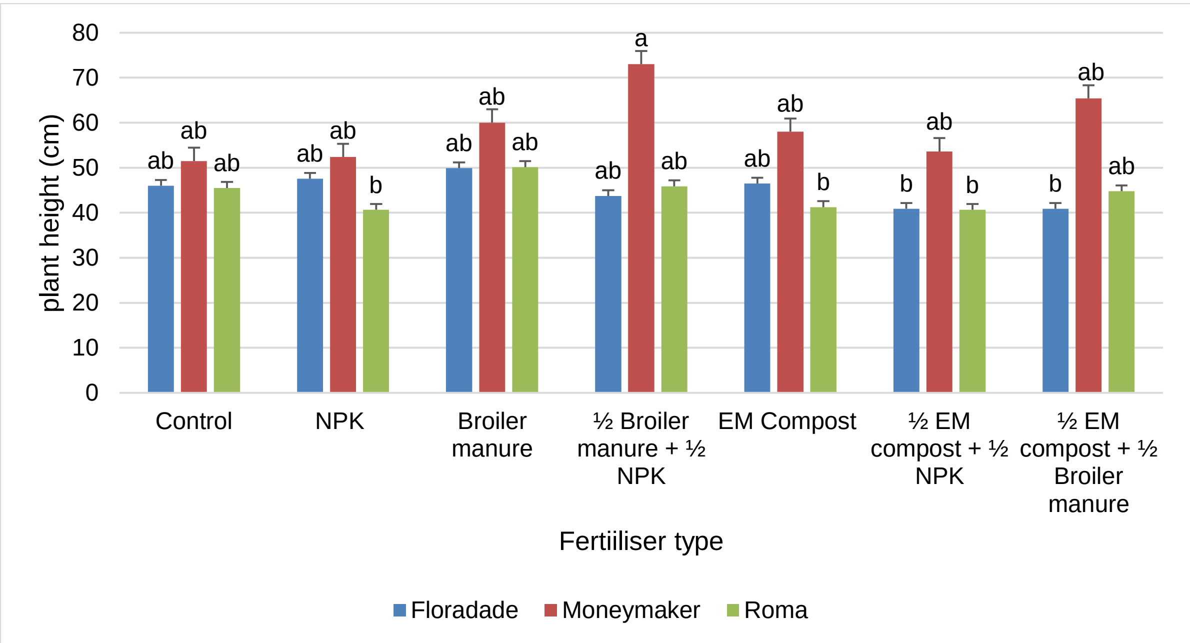

Figure 4.4: Effect of fertiliser application on plant height (cm) of three tomato varieties grown at Horticultural centre (Mankweng) at 10 WAT

Table 4.1: Effect of NPK, EM enriched compost and broiler manure on plant height (cm) of tomato at Apel

	Weeks after transplanting				
Treatment	6	8	10	12	Mean
Variety					
Floradade	34.64a	38.93b	40.93ab	39.99a	38.62
Moneymaker	39.41a	51.41a	48.59a	46.79a	46.55
Roma	26.05a	31.82b	30.84b	27.77a	29.12
Mean	33.37	40.72	40.12	38.18	38.10
Fertiliser type					
Control	28.04a	34.75a	33.33a	33.62a	32.44
NPK	29.58a	36.04a	35.63a	34.47a	33.93
Broiler manure (BM)	38.67a	47.17a	46.71a	40.82a	43.34
½ BM + ½ NPK	33.50a	41.75a	42.42a	39.32a	39.25
EM Compost	36.71a	46.50a	45.92a	42.33a	42.87
½ EM compost + ½ NPK	39.33a	46.04a	46.33a	43.38a	43.77
½ EM compost + ½ BM	27.75a	32.79a	30.50a	33.35a	31.10
Mean	33.37	40.72	40.12	38.18	38.10
F-values					
Fertiliser type	1.83^{ns}	2.15^{ns}	2.63^{ns}	1.18^{ns}	
Variety	4.59^{ns}	12.76^{*}	12.98^{*}	4.23^{ns}	
Variety*fertiliser	0.60^{ns}	0.59^{ns}	0.89^{ns}	1.03^{ns}	

Means followed by the same letter in a column are not significantly different at P ≤ 0.05, ns, *, means: non-significant or significant at P≤ 0.05 or 0.01 or 0.001 respectively

Table 4.2: Effect of NPK, EM enriched compost and broiler manure on plant height (cm) of tomato at Horticultural Centre (Mankweng)

	Weeks after transplanting				
Treatment	6	8	10	12	Mean
Variety					
Floradade	44.39a	41.55b	45.06b	45.41b	44.10
Moneymaker	37.99a	54.88a	59.13a	60.16a	53.04
Roma	37.20a	40.38b	44.11b	45.11b	41.70
Mean	39.86	45.60	49.43	50.23	46.28
Fertiliser type					
Control	36.42a	43.35a	47.67a	49.27a	44.18
NPK	53.31a	43.21a	46.85a	49.70a	48.27
Broiler manure (BM)	39.09a	48.08a	53.33a	53.25a	48.44
½ BM + ½ NPK	41.33a	49.98a	54.21a	52.80a	49.58
EM Compost	37.63a	46.75a	48.58a	49.92a	45.72
½ EM compost + ½ NPK	33.79a	41.38a	45.04a	46.17a	41.59
½ EM compost + ½ BM	37.46a	46.46a	50.33a	50.50a	46.19
Mean	39.86	45.60	49.43	50.23	46.28
F-values					
Fertiliser type	0.75^{ns}	1.11^{ns}	1.53^{ns}	1.50^{ns}	
Variety	0.58^{ns}	9.13*	9.73**	22.59***	
Variety*fertiliser	1.03^{ns}	0.80^{ns}	1.13^{ns}	0.98^{ns}	

Means followed by the same letter in a column are not significantly different at P ≤ 0.05, ns, *, **, ***, means: non-significant or significant at P≤ 0.05 or 0.01 or 0.001 respectively

The stem diameter showed that the tomato variety (V) and fertiliser type (F) as well as V x F interaction had no significant ($P \leq 0.05$) effect on stem diameter of tomato (Tables 4.3 and 4.4) at both Apel and Mankweng sites. The highest average tomato stem diameter of 8.35 cm was recorded at both sites in tomato grown from broiler manure at Apel and 9.85 cm at Mankweng. Study by Makinde *et al.,* 2016 reported non-significant differences in stem diameter of tomato varieties in relation to fertiliser application.

Similar non- significant interactions (V x F) were also recorded for number of branches on tomato plants grown under different treatment combinations. At Apel, highest non-significant value of 9.35 was obtained in broiler manure treatment and highest mean value of 8.89 found in Moneymaker at 12 WAT (Table 4.5). At Mankweng however, tomato grown in sole NPK treatment had the highest non-significant average number of branches 9.63 at 8 WAT, while Roma variety had 9.25 average number of branches during the same growth period (Table 4.6). Although there were no significant differences in number of branches at both sites, the increased branching with fertiliser application may be due to the better availability of soil nutrients which led to better improved vegetative growth.

Table 4.3: Effect of NPK, EM enriched compost and broiler manure on stem diameter of tomato at Apel

	Weeks after transplanting				
Treatment	6	8	10	12	Mean
Variety					
Floradade	7.08a	8.16a	7.97a	8.33a	7.89
Moneymaker	7.13a	8.18a	8.35a	8.56a	8.06
Roma	6.10a	7.24a	6.87a	6.48a	6.67
Mean	6.77	7.86	7.73	7.79	7.54
Fertiliser type					
Control	6.09a	7.23a	6.69a	7.06a	6.77
NPK	5.98a	6.42a	6.74a	6.95a	6.52
Broiler manure (BM)	7.54a	8.76a	8.70a	8.39a	8.35
½ BM + ½ NPK	7.38a	8.53a	8.29a	7.81a	8.00
EM Compost	7.04a	8.39a	8.42a	8.48a	8.08
½ EM compost + ½ NPK	7.38a	8.57a	8.26a	8.39a	8.15
½ EM compost + ½ BM	5.98a	7.11a	7.10a	7.43a	6.91
Mean	6.77	7.86	7.73	7.79	7.54
F-values					
Fertiliser type	1.76^{ns}	2.12^{ns}	1.68^{ns}	0.86^{ns}	
Variety	1.74^{ns}	1.53^{ns}	4.33^{ns}	2.77^{ns}	
Variety*fertiliser	0.75^{ns}	0.81^{ns}	1.01^{ns}	0.96^{ns}	

Means followed by the same letter in a column are not significantly different at P ≤ 0.05, ns means: non-significant at P ≤ 0.05

Table 4.4: Effect of NPK, EM enriched compost and broiler manure on stem diameter (mm) of tomato at Horticultural Centre (Mankweng)

Treatment	Weeks after transplanting				
	6	8	10	12	Mean
Variety					
Floradade	9.68a	8.65a	8.98a	9.54a	9.21
Moneymaker	9.34a	8.94a	9.51a	9.34a	7.28
Roma	8.75a	8.87a	9.58a	9.65a	9.21
Mean	9.26	8.82	9.36	9.51	8.57
Fertiliser type					
Control	8.71a	8.84a	9.13a	9.60a	9.07
NPK	10.35a	8.70a	9.05a	9.40a	9.38
Broiler manure (BM)	9.54a	9.81a	10.18a	9.86a	9.85
½ Broiler manure + ½ NPK	9.91a	9.09a	9.87a	9.77a	9.66
EM Compost	8.79a	8.51a	9.34a	9.48a	9.03
½ EM compost + ½ NPK	8.54a	8.17a	8.98a	9.29a	8.75
½ EM compost + ½ BM	8.96a	8.61a	8.94a	9.15a	8.92
Mean	9.26	8.82	9.36	9.51	8.57
F-values					
Fertiliser type	1.96^{ns}	1.66^{ns}	1.32^{ns}	0.95^{ns}	
Variety	0.80^{ns}	0.26^{ns}	0.90^{ns}	0.74^{ns}	
Variety*fertiliser	1.73^{ns}	0.92^{ns}	0.51^{ns}	1.06^{ns}	

Means followed by the same letter in a column are not significantly different at P ≤ 0.05, ns means: non-significant at P ≤ 0.05

Table 4.5: Effect of NPK, EM enriched compost and broiler manure on number of branches of tomato at Apel

	Weeks after transplanting				
Treatment	6	8	10	12	Mean
Variety					
Floradade	5.64a	8.38a	6.50a	7.96a	7.12
Moneymaker	6.86a	10.00a	7.50a	8.89a	8.31
Roma	4.75a	8.41a	6.71a	6.76a	6.66
Mean	5.75	8.93	6.90	7.87	7.36
Fertiliser type					
Control	3.96a	6.38a	4.99a	7.27a	4.65
NPK	5.00a	8.13a	5.71a	6.92a	6.44
Broiler manure (BM)	6.88a	10.29a	8.17a	9.35a	8.67
½ Broiler manure + ½ NPK	6.75a	10.67a	7.87a	8.27a	8.39
EM Compost	6.67a	9.96a	7.63a	7.68a	7.99
½ EM compost + ½ NPK	6.46a	10.25a	8.21a	9.08a	8.50
½ EM compost + ½ BM	4.54a	6.83a	5.79a	6.52a	5.92
Mean	5.75	8.93	6.90	7.87	7.36
F-values					
Fertiliser type	2.50^{ns}	2.97^{ns}	2.66^{ns}	0.99^{ns}	
Variety	2.66^{ns}	2.96^{ns}	0.56^{ns}	1.30^{ns}	
Variety*fertiliser	0.61^{ns}	0.31^{ns}	0.49^{ns}	0.82^{ns}	

Means followed by the same letter in a column are not significantly different at $P \leq 0.05$, ns means: non-significant at $P \leq 0.05$

Table 4.6: Effect of NPK, EM enriched compost and broiler manure on number of branches of tomato at Horticultural Centre (Mankweng)

	Weeks after transplanting				
Treatment	6	8	10	12	Mean
Variety					
Floradade	6.00a	8.00a	10.96a	10.77ab	8.93
Moneymaker	6.96a	9.11a	11.04a	9.35b	9.12
Roma	6.80a	9.25a	11.09a	11.65a	9.69
Mean	6.59	8.79	11.03	10.59	9.25
Fertiliser type					
Control	6.67a	8.75a	10.17a	9.60a	8.79
NPK	7.46a	9.63a	12.25a	11.23a	10.64
Broiler manure (BM)	7.13a	9.42a	11.54a	11.43a	9.88
½ Broiler manure + ½ NPK	7.04a	9.17a	12.67a	11.38a	10.07
EM Compost	6.50a	8.83a	11.04a	9.83a	9.05
½ EM compost + ½ NPK	5.13a	7.25a	9.25a	10.32a	7.99
½ EM compost + ½ BM	6.21a	8.46a	10.29a	10.33a	8.82
Mean	6.59	8.79	11.03	10.59	9.25
F-values					
Fertiliser type	1.80^{ns}	1.73^{ns}	2.12^{ns}	1.47^{ns}	
Variety	0.71^{ns}	1.28^{ns}	0.00^{ns}	8.94*	
Variety*fertiliser	0.62^{ns}	0.79^{ns}	0.53^{ns}	0.39^{ns}	

Means followed by the same letter in a column are not significantly different at P ≤ 0.05, ns, *, means: non-significant or significant at P ≤ 0.05 respectively

Chlorophyll content is largely determined by plants nutrition, health status and exposure to sunlight. Nitrogen (N) is a constituent of chlorophyll molecule and also the main constituent of all amino acids in proteins and lipids that acts as a structural compounds of the chloroplast (Ouda and Mahadeen, 2008). In this study, the fertiliser type and tomato variety had no significant (P ≤ 0.05) effect on chlorophyll content at both sites. Although at Mankweng at 6 WAT, the highest average value of 50.49 (Floradade) and Moneymaker (42.85) were found in broiler manure treatment while (39.03) for Roma was found in sole NPK treatment. Furthermore, the least average values 24.96 and 25.23 were obtained in Moneymaker grown in ½ EM compost + ½ NPK and sole EM compost treatments respectively (Figure 4.5). Comparing the fertiliser types at Apel, significantly highest average chlorophyll contents (42.09) were obtained in tomato grown in broiler manure treatment at 12 WAT (Table 4.7) whereas the least significant value (27.87) was recorded in EM compost treatment. Similar trend was recorded for Mankweng (Table 4.8). Significant differences among the tomato varieties were recorded at Apel at 10 WAT. Moneymaker had the highest average value of 39.87, Floradade (33.88) and Roma (31.61). The differences obtained in chlorophyll contents across the varieties of tomato grown at Mankweng were not significant (Table 4.8).

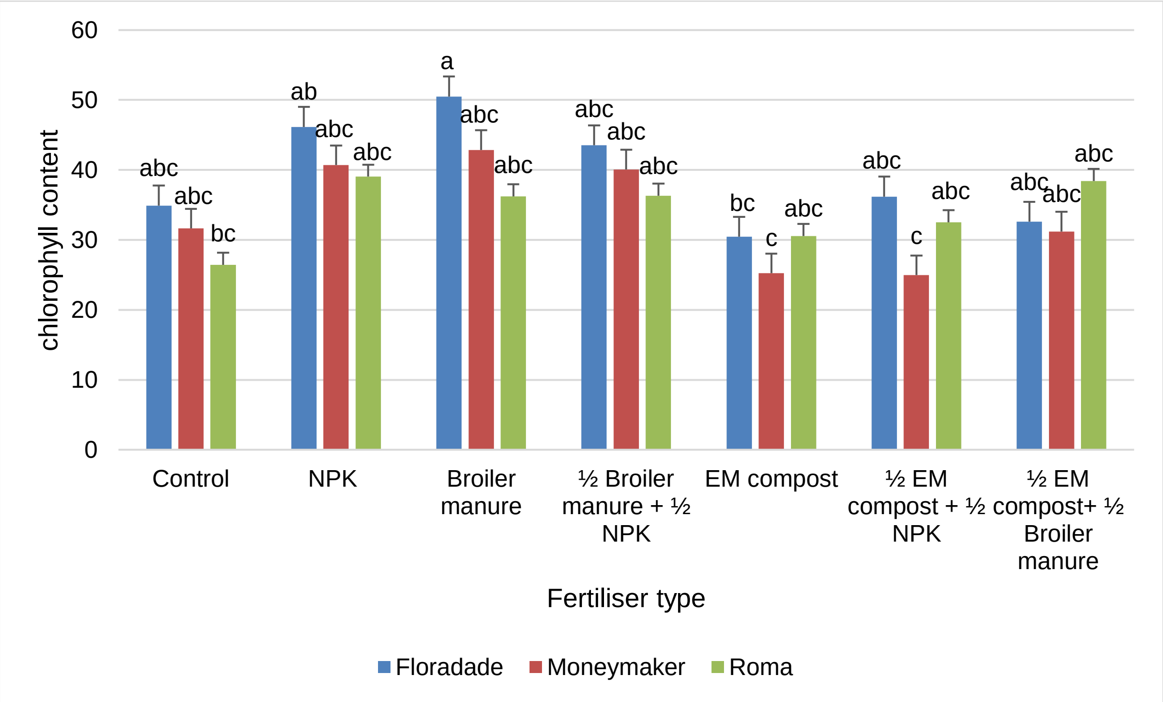

Figure 4.5: Effect of fertiliser application on chlorophyll content of three tomato varieties grown at Horticultural centre (Mankweng) at 6 WAT

Table 4.7: Effect of NPK, EM enriched compost and broiler manure on chlorophyll content of tomato at Apel

	Weeks after transplanting				
Treatment	6	8	10	12	Mean
Variety					
Floradade	50.62a	43.12a	33.88ab	33.65a	40.32
Moneymaker	50.69a	43.39a	39.87a	38.37a	86.16
Roma	45.99a	39.65a	31.61b	33.59a	37.71
Mean	49.10	42.05	35.12	35.20	54.73
Fertiliser type					
Control	46.03a	38.59a	34.34ab	34.13abcd	38.27
NPK	47.98a	41.75a	38.23a	39.08abc	41.76
Broiler manure (BM)	50.89a	41.40a	39.89a	42.09a	43.57
½ Broiler manure + ½ NPK	47.99a	45.82a	39.76a	39.92ab	43.37
EM Compost	52.36a	42.18a	28.41b	27.87d	37.71
½ EM compost + ½ NPK	53.49a	46.56a	31.05ab	31.05cd	40.54
½ EM compost + ½ BM	44.96a	38.05a	34.13ab	32.29bcd	37.36
Mean	49.10	42.05	35.12	35.20	54.73
F-values					
Fertiliser type	0.67^{ns}	0.52^{ns}	4.40***	7.82***	
Variety	0.84^{ns}	1.07^{ns}	6.97*	2.24^{ns}	
Variety*fertiliser	0.62^{ns}	0.49^{ns}	1.97^{ns}	1.38^{ns}	

Means followed by the same letter in a column are not significantly different at P ≤ 0.05, ns, *, **, ***, means: non-significant or significant at P ≤ 0.05 or 0.01 or 0.001 respectively

Table 4.8: Effect of NPK, EM enriched compost and broiler manure on chlorophyll content of tomato at Horticultural Centre (Mankweng)

	Weeks after transplanting				
Treatment	6	8	10	12	Mean
Variety					
Floradade	39.19a	36.29a	42.18a	38.09a	38.54
Moneymaker	33.80b	36.75a	40.51a	36.49a	37.29
Roma	34.21ab	36.37a	38.88a	35.52a	36.25
Mean	35.73	36.47	40.52	36.70	37.36
Fertiliser type					
Control	31.00bc	34.74ab	37.32a	33.71ab	34.19
NPK	41.95a	37.79ab	45.52a	38.83ab	41.02
Broiler manure (BM)	43.19a	38.16ab	44.48a	39.96ab	41.45
½ Broiler manure + ½ NPK	39.98ab	42.04a	43.49a	42.99a	42.13
EM Compost	28.74c	33.52ab	36.08a	32.59ab	32.73
½ EM compost + ½ NPK	31.22bc	30.44b	36.19a	29.63b	31.87
½ EM compost + ½ BM	34.07abc	38.59ab	40.60a	39.22ab	39.37
Mean	35.73	36.47	40.52	36.70	37.36
F-values					
Fertiliser type	7.68***	2.21*	2.61^{ns}	3.25**	
Variety	6.03*	0.01^{ns}	0.34^{ns}	0.25^{ns}	
Variety*fertiliser	1.11^{ns}	0.40^{ns}	0.53^{ns}	0.77^{ns}	

Means followed by the same letter in a column are not significantly different at P ≤ 0.05, ns, *, **, ***, means: non-significant or significant at P ≤ 0.05 or 0.01 or 0.001 respectively

4.2. Effect of EM enriched compost, inorganic fertiliser and poultry manure on yield and yield components of three tomato varieties

Application of broiler manure EM-enriched compost, and NPK fertilisers solely or in combination did not result in any significant interactions V x F in relation to fresh shoot, root and fruit mass of tomato. Comparing the fertiliser types, significant differences were obtained in fresh shoot and root masses at Apel at 12 WAT (Table 4.9). The significantly highest fresh root mass (31.99 g) was found in ½ EM + ½ NPK treatment, while the least value (10.90 g) was obtained in sole NPK treatment. All other fresh masses both at 8 and 12 WAT were not significantly different, including the variations recorded among the tomato varieties. Similar non-significant differences for fresh shoot, root and fruit masses were recorded at Mankweng (Table 4.10). The results concur with the findings by Ouda and Mahadeen (2008), as there were no significant differences in fresh shoot mass in broccoli plants under different fertiliser treatments.

Significant ($P \leq 0.05$) differences were obtained in the interactions between variety (V) and fertiliser (F) in relation to dry shoot mass of tomato at Mankweng (Appendix 4.3) and dry fruit mass Apel at 12 WAT (Appendix 4.4). The significantly highest average tomato dry shoot mass at Mankweng at 12 WAT, (240.30 g) was obtained in Roma grown in sole broiler manure treatment, (149.27 g) for Floradade in sole NPK and (138.50 g) for Moneymaker in ½ broiler manure + ½ NPK treatment (Figure 4.6). Regarding dry fruit mass at 12 WAT for tomato grown at Apel, the significantly highest mean values (47.20 g) was found in Moneymaker grown EM compost treated soil, (32.95 g) for Roma in ½ EM + ½ broiler manure treatment and (31.23 g) for Floradade in ½ EM + ½ NPK treatment (Figure 4.7). The higher dry fruit and shoot mass in treatments containing organic fertiliser might be due to the availability of nutrients especially nitrogen and improvement of soil water holding capacity. According to Arisha *et al.,* 2003, organic manure activates many species of living organisms, which release phytohormones and may stimulate the plant growth and absorption of nutrients. Such organisms need nitrogen for multiplication. Therefore, this is plausible reason that the use of organic manure had beneficial effect on dry matter accumulation. The other dry masses, comparing the varieties or the fertiliser types at both Apel and Mankweng were not significantly different (Tables 4.11 and 4.12).

Table 4.9: Effect of fertiliser application on fresh shoot, root and fruit mass (g) of tomato varieties grown at Apel

	8 WAT				12 WAT			
Treatment	Fresh shoot Mass	Fresh root mass	Fresh fruit mass	Mean	Fresh shoot mass	Fresh root mass	Fresh fruit mass	Mean
Variety								
Floradade	94.98a	7.04a	44.18a	48.73	175.99a	21.95a	103.12a	100.35
Moneymaker	105.44a	6.84a	30.04a	47.44	204.28a	28.02a	120.58a	117.63
Roma	80.13a	18.35a	12.02a	36.83	156.95a	19.71a	50.75a	75.80
Mean	93.52	10.74	28.75	44.33	179.07	23.23	91.48	97.93
Fertiliser type								
Control	96.34a	5.45a	19.01a	40.29	141.76b	19.18ab	41.03a	67.32
NPK	73.31a	6.07a	22.60a	33.99	123.93b	10.90b	58.60a	64.48
Broiler manure (BM)	131.18a	11.70a	35.15a	59.34	228.07ab	27.46ab	68.74a	108.09
½ Broiler manure + ½ NPK	92.94a	7.00a	44.84a	48.26	226.98ab	27.82ab	158.58a	137.79
EM Compost	86.76a	31.64a	28.13a	48.84	140.37b	21.47ab	81.74a	81.19
½ EM compost + ½ NPK	97.34a	7.52a	35.75a	46.87	256.93a	31.99a	133.61a	140.84
½ EM compost + ½ BM	76.74a	5.80a	25.74a	36.09	13.45b	23.76ab	97.80a	85.67
Mean	93.52	10.74	28.75	44.33	179.07	23.23	91.48	97.93
F-values								
Fertiliser type	0.88^{ns}	0.97^{ns}	0.94^{ns}		4.51**	2.76*	1.93^{ns}	
Variety	0.39^{ns}	1.03^{ns}	1.47^{ns}		1.70^{ns}	1.40^{ns}	3.38^{ns}	
Variety*fertiliser	0.49^{ns}	1.00^{ns}	0.52^{ns}		1.30^{ns}	0.88^{ns}	1.44^{ns}	

Means followed by the same letter in a column are not significantly different at P ≤ 0.05, ns, *, **, means: non-significant or significant at P ≤ 0.05 or 0.01 or 0.001 respectively

Table 4.10: Effect of fertiliser application on fresh shoot, root and fruit mass (g) of tomato varieties grown at Horticultural centre (Mankweng)

Treatment	8 WAT				12 WAT			
	Fresh shoot Mass	Fresh root mass	Fresh fruit mass	Mean	Fresh shoot mass	Fresh root mass	Fresh fruit mass	Mean
Variety								
Floradade	188.69a	14.91a	63.19a	88.93	505.30ab	42.81a	1181.60a	576.57
Moneymaker	143.49a	8.84b	49.59a	67.31	382.41b	37.88a	973.60a	464.63
Roma	281.62a	15.13a	67.13a	121.29	679.59a	54.56a	1330.20a	688.12
Mean	204.60	12.96	59.97	92.51	522.43	45.08	1161.80	576.44
Fertiliser type								
Control	183.63a	11.39a	75.38a	90.13	584.24a	51.18a	1275.50a	639.97
NPK	203.79a	15.81a	64.49a	94.69	485.62a	37.88a	1157.90a	560.47
Broiler manure (BM)	233.90a	14.18a	66.73a	270.32	547.70a	43.89a	1428.70a	673.43
½ Broiler manure + ½ NPK	272.28a	15.11a	64.63a	88.01	582.60a	75.54a	1268.70a	642.28
EM Compost	182.17a	12.91a	61.90a	85.66	385.53a	37.03a	924.30a	448.95
½ EM compost + ½ NPK	183.61a	10.79a	52.30a	82.23	601.30a	37.44a	1046.60a	564.78
½ EM compost + ½ BM	172.82a	10.52a	34.37a	72.57	470.03a	32.65a	1030.70a	511.13
Mean	204.60	12.96	59.97	92.51	522.43	45.08	1161.80	576.44
F-values								
Fertiliser type	1.35^{ns}	1.40^{ns}	0.82^{ns}		0.84^{ns}	0.81^{ns}	0.72^{ns}	
Variety	4.65^{ns}	8.34*	0.45^{ns}		9.10*	0.99^{ns}	0.55^{ns}	
Variety*fertiliser	0.91^{ns}	0.69^{ns}	0.85^{ns}		0.77^{ns}	1.00^{ns}	0.55^{ns}	

Means followed by the same letter in a column are not significantly different at P ≤ 0.05, ns, *, means: non-significant or significant at P ≤ 0.05 respectively

Table 4.11: Effect of fertiliser application on dry shoot, root and fruit mass (g) of tomato varieties grown at Apel

Treatment	8 WAT				12 WAT			
Variety	Dry shoot Mass	Dry root mass	Dry fruit mass	Mean	Dry shoot mass	Dry root mass	Dry fruit mass	Mean
Floradade	19.66a	1.95a	5.86a	9.16	69.39a	9.91a	24.07a	34.46
Moneymaker	16.37a	1.39a	2.39a	6.72	85.12a	11.67a	27.28a	41.36
Roma	10.12a	1.24a	1.01a	4.12	65.84a	11.95a	21.32a	33.04
Mean	15.38	1.53	3.09	6.67	73.45	11.18	24.22	36.29
Fertiliser type								
Control	10.53a	1.19a	1.06a	4.26	46.31a	7.88a	12.53a	22.24
NPK	14.68a	1.81a	5.10a	7.20	57.05a	8.88a	19.75a	28.56
Broiler manure (BM)	14.88a	1.18a	2.64a	6.23	80.38a	10.56a	20.53a	37.16
½ Broiler manure + ½ NPK	17.05a	1.37a	1.98a	6.80	41.37a	12.15a	27.30a	26.94
EM Compost	14.83a	1.49a	1.48a	5.93	59.13a	9.25a	32.07a	23.48
½ EM compost + ½ NPK	15.12a	1.57a	3.83a	6.84	131.14a	15.50a	30.83a	59.16
½ EM compost + ½ BM	20.57a	2.09a	5.51a	9.39	48.70a	14.03a	26.55a	29.76
Mean	15.38	1.53	3.09	6.67	73.45	11.18	24.22	36.29
F-values								
Fertiliser type	0.78^{ns}	1.50^{ns}	0.85^{ns}		2.25^{ns}	0.77^{ns}	2.05^{ns}	
Variety	0.93^{ns}	0.59^{ns}	1.20^{ns}		0.57^{ns}	0.49^{ns}	0.89^{ns}	
Variety*fertiliser	0.88^{ns}	1.25^{ns}	1.05^{ns}		0.95^{ns}	1.15^{ns}	1.41^{ns}	

Means followed by the same letter in a column are not significantly different at P ≤ 0.05, ns, *, means: non-significant or significant at P ≤ 0.05 respectively

Table 4.12: Effect of fertiliser application on dry shoot, root and fruit mass (g) of tomato varieties grown at Horticultural centre (Mankweng)

	8 WAT				12 WAT			
Treatment	Dry shoot Mass	Dry root mass	Dry fruit mass	Mean	Dry shoot mass	Dry root mass	Dry fruit mass	Mean
Variety								
Floradade	33.46a	4.45a	4.63a	14.18	120.25ab	15.20a	46.22a	60.56
Moneymaker	32.24a	3.71a	3.21a	13.05	94.79b	12.71a	48.40a	51.97
Roma	55.05a	4.23a	3.45a	20.91	186.62a	12.90a	58.33a	85.95
Mean	40.25	4.13	3.76	16.05	133.89	13.60	50.98	66.16
Fertiliser type								
Control	31.76a	3.30a	3.89a	12.98	119.52a	11.92a	49.05a	86.83
NPK	47.25a	4.30a	4.34a	18.63	140.10a	14.73a	56.62a	70.48
Broiler manure (BM)	43.14a	5.40a	2.05a	16.86	164.09a	16.83a	53.23a	78.05
½ Broiler manure + ½ NPK	55.34a	5.91a	6.63a	22.63	155.05a	12.82a	61.33a	76.40
EM Compost	46.35a	4.70a	3.84a	18.29	119.06a	13.35a	48.10a	86.84
½ EM compost + ½ NPK	29.70a	1.78a	3.18a	11.55	123.57a	14.47a	41.28a	59.77
½ EM compost + ½ BM	28.23a	3.51a	2.41a	11.38	115.79a	11.11a	47.28a	58.06
Mean	40.25	4.13	3.76	1 6.05	133.89	13.60	50.98	66.16
F-values								
Fertiliser type	1.03^{ns}	1.40^{ns}	1.27^{ns}		2.87^{ns}	1.09^{ns}	0.90^{ns}	
Variety	0.96^{ns}	0.23^{ns}	0.54^{ns}		9.43*	0.93^{ns}	2.06^{ns}	
Variety*fertiliser	0.86^{ns}	0.90^{ns}	0.44^{ns}		1.21^{ns}	0.73^{ns}	1.62^{ns}	

Means followed by the same letter in a column are not significantly different at P ≤ 0.05, ns, *, means: non-significant or significant at P ≤ 0.05 or 0.01 respectively

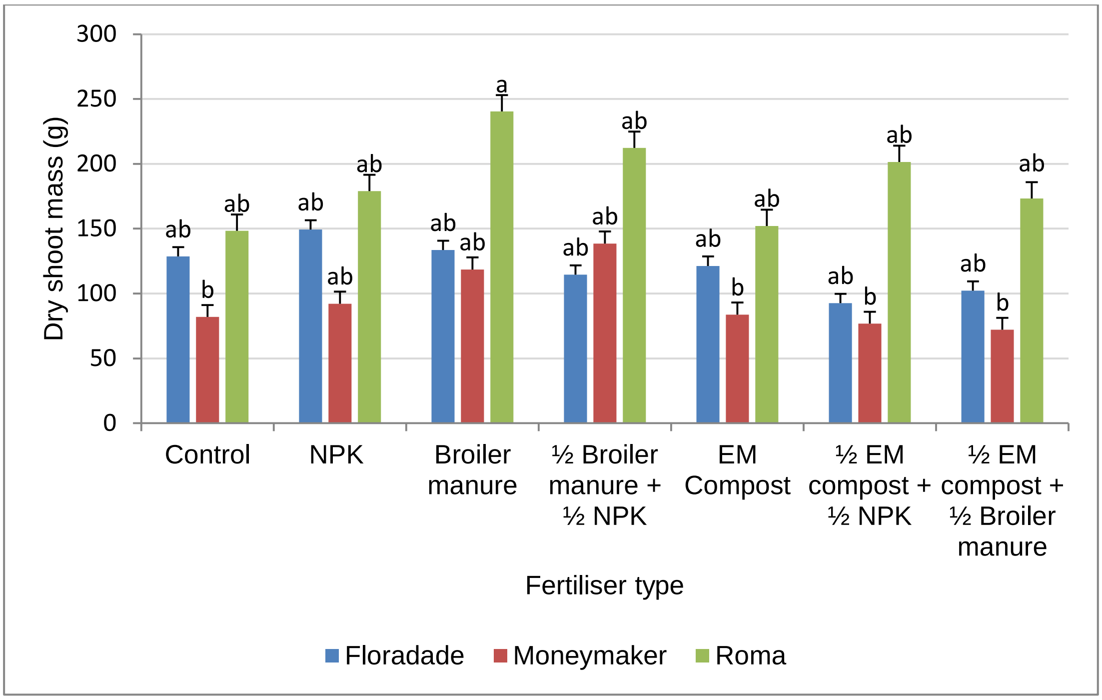

Figure 4.6: Effect of fertiliser application on dry shoot mass (g) of three tomato varieties grown at Mankweng at 12 WAT

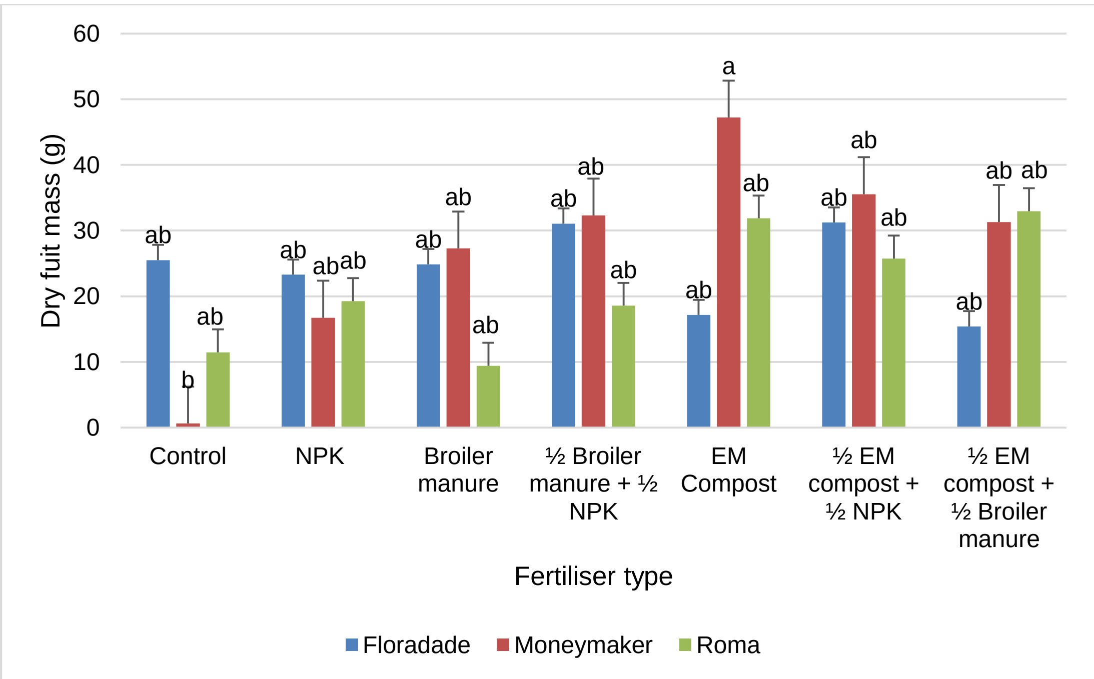

Figure 4.7: Effect of fertiliser application on dry fruit mass (g) of three tomato varieties grown at Apel at 12 WAT

The interactions obtained between V x F regarding number of fruits produced by tomato at both sites (Apel and Mankweng) were not significant (Table 4.13 and 4.15). At Apel highest average number of tomato fruits at 8, 10 and 12 WAT were recorded in ½ EM + ½ NPK treatment, while the least values were found in the control (Table 4.13). Whereas at Mankweng the variation in number of tomato fruits under different fertiliser treatments were not significant (Table 4.14). In the same vein at Apel, the tomato varieties did not differ significantly in number of fruit produce, while at Mankweng, significant differences were recorded at 6, 8 and 12 WAT. At 12 WAT, Roma had the significantly highest average number of fruits (21.66) compared to 13. 26 (Moneymaker) and 8.73 (Floradade). Thus, Roma performed better than Moneymaker and Floradade under the different fertiliser regimes. This agrees with findings by Agyeman *et al.,* 2014 who reported that differences in fruit yield of tomato varieties could be due to their distinct growth habit. Therefore, the higher yield observed in Roma over Floradade could be due to inherent genetic component which enhanced better utilisation of nutrients leading to production of higher number of fruits per plant.

In terms of fruit size (diameter) there were no significant interactions (V x F), and also the varieties did not differ significantly. Likewise, the fertiliser types did not differ significantly from each other with their influence on tomato fruit diameter (Table 4.15). However, this was contrary to the findings by Ilupeju *et al.,* 2015 where by significant differences in fruit diameter in relation to fertiliser application on three tomato varieties was reported.

Table 4.13: Effect of NPK, EM enriched compost and broiler manure on number of fruits of tomato at Apel

	Weeks after transplanting				
Treatment	6	8	10	12	Mean
Variety					
Floradade	1.55a	3.86a	3.93a	3.31a	3.16
Moneymaker	1.82a	6.00a	5.41a	3.82a	4.26
Roma	1.13a	3.27a	3.13a	2.04a	2.39
Mean	1.50	4.38	4.16	3.06	3.27
Fertiliser type					
Control	0.58a	1.83b	1.79b	1.38b	1.39
NPK	1.25a	3.25ab	3.38ab	3.22ab	2.78
Broiler manure (BM)	1.50a	5.04ab	4.96ab	2.65ab	3.54
½ Broiler manure + ½ NPK	1.75a	5.00ab	4.67ab	3.70ab	3.78
EM Compost	1.42a	4.33ab	3.92ab	3.10ab	3.19
½ EM compost + ½ NPK	2.54a	6.83a	6.42a	4.68a	5.12
½ EM compost + ½ BM	1.46a	4.33ab	3.96ab	2.68ab	3.11
Mean	1.50	4.38	4.16	3.06	3.27
F-values					
Fertiliser type	1.59^{ns}	2.66*	2.28*	1.89*	
Variety	0.75^{ns}	2.20^{ns}	1.23^{ns}	0.98^{ns}	
Variety*fertiliser	1.33^{ns}	0.96^{ns}	1.00^{ns}	1.40^{ns}	

Means followed by the same letter in a column are not significantly different at P ≤ 0.05, ns, *, means: non-significant or significant at P≤ 0.05 respectively

Table 4.14: Effect of NPK, EM enriched compost and broiler manure on number of fruits of tomato at Horticultural Centre (Mankweng)

	Weeks after transplanting				
Treatment	6	8	10	12	Mean
Variety					
Floradade	2.00b	2.86b	7.19a	8.73b	5.19
Moneymaker	3.75ab	5.32ab	11.19a	13.26b	8.38
Roma	5.46a	6.98a	14.66a	21.66a	12.19
Mean	3.74	5.05	11.01	14.55	8.59
Fertiliser type					
Control	4.25a	5.54a	11.67a	14.32a	8.95
NPK	2.96a	4.42a	10.42a	14.33a	8.03
Broiler manure (BM)	4.54a	5.75a	12.92a	17.37a	10.15
½ Broiler manure + ½ NPK	4.58a	5.71a	14.38a	18.38a	10.76
EM Compost	3.75a	5.29a	10.13a	11.70a	7.72
½ EM compost + ½ NPK	3.29a	4.50a	7.71a	11.60a	6.78
½ EM compost + ½ BM	2.79a	4.17a	9.92a	14.17a	7.76
Mean	3.74	5.05	11.01	14.55	8.59
F-values					
Fertiliser type	0.50^{ns}	0.32^{ns}	1.21^{ns}	1.49^{ns}	
Variety	5.47*	5.91*	3.50^{ns}	11.59**	
Variety*fertiliser	1.19^{ns}	1.13^{ns}	0.71^{ns}	0.74^{ns}	

Means followed by the same letter in a column are not significantly different at P ≤ 0.05, ns, *, **, means: non-significant or significant at P ≤ 0.05 or 0.01 respectively

Table 4.15: Effect of NPK, EM enriched compost and poultry manure on fruit diameter (cm) of tomato grown at Horticultural centre (Mankweng)

Treatment	
Variety	
Floradade	37.22a
Moneymaker	37.58a
Roma	29.81a
Mean	
Fertiliser type	
Control	37.13a
NPK	35.01a
Broiler manure (BM)	37.52a
½ Broiler manure + ½ NPK	32.71a
EM Compost	36.15a
½ EM compost + ½ NPK	34.31a
½ EM compost + ½ BM	31.27a
Mean	
F-values	
Fertiliser type	1.05^{ns}
Variety	3.92^{ns}
Variety*fertiliser	1.04^{ns}

Means followed by the same letter in a column are not significantly different at $P \leq 0.05$, ns means: non-significant at $P \leq 0.05$

4.3. Effects of organic and inorganic fertilisers on shoot nutrient composition of three tomato varieties

Organic and inorganic fertiliser application generally improved the concentration of potassium in tomato, potassium which is important in enhancing fruit colour, quality and reduce incidence of diseases. Similarly, according to Adekiya and Agbede, (2009) all levels of broiler manure alone and NPK + broiler manure increases shoot nutrient amounts in tomato significantly, hence, the concentration of nutrients increased with the amount of broiler manure. Fertiliser application can improve the mineral content of the tomato, this was evident by the investigation by Makinde *et al*., 2016 who observed that mineral content of tomato varieties was improved by soil fertiliser application. In this study, the results showed that there were significant differences for K, Zn, Mn and Fe contents of tomato grown at Apel in relation to fertiliser treatments (Table 4.16). Comparing the fertiliser treatments tomato grown in soil treated with ½ broiler manure + ½ NPK had the significantly highest average (3.01 %) K content while the least value (2.65 %) was obtained in the control (Table 4.16). Similarly, significantly highest mean (44.33 mg kg^{-1}) Zn was found in crops grown in the same treatment, but the lowest significant value (36.50 mg kg^{-1}) was obtained in ½ EM + ½ NPK treatment. For Mn and Fe contents in tomato significantly highest mean values (150.17 mg kg^{-1} and 2381 mg kg^{-1}) for Mn and Fe respectively were found in sole broiler manure treatment while the least values 114.83 mg kg^{-1} and 1357.6 mg kg^{-1} for Mn and Fe respectively were found in ½ EM compost + ½ NPK and sole NPK treatments respectively (Table 4.16). The results agreed with the findings of Ouda and Mahadeen, (2008) in broccoli. The effect of fertiliser on Fe uptake, could be due to the reason that organic carbon acts as a source of energy for soil microorganisms, which upon mineralisation releases organic acids that decreased soil pH and improves availability of Fe (Adediran *et al.,* 2004; Ouda and Mahadeen, 2008). The differences obtained in other macro and micro nutrient contents of tomato in relation to fertiliser treatments at both Apel and Mankweng (Tables 4.16 and 4.17) were not significant. Similar non-significant differences were found for the protein contents of tomato in response to fertiliser treatments (Table 4.18).

Table 4.16: Effect of organic and inorganic fertiliser and their combination on shoot nutrient composition of tomato crop at Apel at harvest (12 WAT)

Treatments	%					$mg\ kg^{-1}$					
	N	Ca	Mg	K	P	Na	Zn	Cu	Mn	Fe	Al
Variety											
Floradade	3.62a	2.31a	3.36a	2.84a	0.27a	2985.1a	38.36a	12.69a	108.57a	2146.9a	2218.0a
Money maker	3.35a	2.41a	1.39a	2.77a	0.24a	2827.5a	35.21a	11.97a	118.21a	2161.9a	2384.1a
Roma	3.14a	2.94a	1.30a	2.72a	0.24a	1716.2a	48.86a	11.30a	165.71a	2004.2a	2925.3a
Fertiliser type											
Control	3.26a	2.65a	1.44a	2.65b	0.24a	2556.2a	38.83abc	12.33a	122.33ab	2283.0a	2548.5a
NPK	3.31a	2.54a	1.27a	2.75ab	0.25a	2282.4a	40.83abc	11.95a	133.67ab	1357.6b	2509.0a
Broiler manure (BM)	3.38a	2.72a	1.35a	2.71ab	0.25a	2289.5a	43.50ab	12.25a	150.17a	2381.3a	2835.7a
½ BM + ½ NPK	3.44a	2.53a	1.28a	3.01a	0.26a	2505.5a	44.33a	12.45a	148.00a	2094.3ab	2396.2a
EM Compost	3.40a	2.46a	1.36a	2.79ab	0.25a	2666.9a	44.00a	11.00a	125.33ab	2041.3ab	2248.7a
½ EM compost + ½ NPK	3.38a	2.49a	1.33a	2.71ab	0.26a	2486.3a	36.50c	11.55a	114.83b	2137.7ab	2354.8a
½ EM compost + ½ BM	3.41a	2.50a	1.44a	2.81ab	0.26a	2780.6a	37.67bc	12.35a	121.50ab	2435.0a	2671.2
F-values											
Fertiliser type	2.53^{ns}	0.88^{ns}	2.53^{ns}	3.21*	1.19^{ns}	1.35^{ns}	5.90**	2.36^{ns}	4.42**	3.51*	0.47^{ns}
Variety	8.08^{ns}	6.47^{ns}	6.41^{ns}	0.43^{ns}	13.72^{ns}	14.22^{ns}	13.01^{ns}	0.57^{ns}	9.76^{ns}	0.09^{ns}	1.85^{ns}
Variety*Fertiliser	5.32^{ns}	1.86^{ns}	4.59^{ns}	5.61^{ns}	0.84^{ns}	0.93^{ns}	10.02^{ns}	4.65^{ns}	3.35^{ns}	2.55^{ns}	1.70^{ns}

Means followed by the same letter in a column are not significantly different at $P \leq 0.05$, ns, *, **, means: non-significant or significant at $P \leq 0.05$ or 0.01 respectively

Table 4.17: Effect of organic and inorganic fertiliser and their combination on shoot nutrient composition of tomato crop at Horticultural centre (Mankweng) at harvest (12 WAT)

Treatments	%					mg kg^{-1}					
	N	Ca	Mg	K	P	Na	Zn	Cu	Mn	Fe	Al
Variety											
Floradade	3.01a	3.52a	0.66a	3.19a	0.29a	887.62a	263.21a	26.93a	292.86a	2984.4a	4095.1a
Money maker	2.52a	3.28a	0.64a	3.01a	0.24a	844.51a	140.43a	19.47a	264.93a	2756.6a	3734.7a
Roma	2.89a	4.39a	0.68a	2.51a	0.27a	643.02a	204.79a	36.36a	285.86a	3527.1a	4933.2a
Fertiliser type											
Control	2.61a	3.80a	0.64a	2.61a	0.28a	746.56a	219.33a	63.13a	248.33a	3495.2a	4741.8a
NPK	2.84a	3.75a	0.67a	2.98a	0.28a	658.08a	186.67a	15.07a	321.33a	3126.5a	4236.5a
Broiler manure (BM)	2.84a	3.74a	0.67a	2.91a	0.26a	785.58a	179.67a	14.57a	246.33a	2786.3a	3827.7a
½ BM + ½ NPK	2.97a	3.64a	0.68a	2.99a	0.26a	829.48a	176.33a	14.93a	289.83a	2905.0a	4082.5a
EM Compost	2.83a	3.68a	0.64a	2.99a	0.27a	879.46a	231.33a	15.15a	305.83a	2942.7a	4022.2a
½ EM compost + ½ NPK	2.71a	3.66a	0.66a	3.02a	0.27a	798.66a	208.83a	14.85a	272.17a	3098.3a	4328.8a
½ EM compost + ½ BM	2.86a	3.86a	0.67a	2.84a	0.27a	844.22a	217.50a	55.40a	284.67a	3271.5a	4550.8a
F-values											
Fertiliser type	1.76^{ns}	0.60^{ns}	0.48^{ns}	1.43^{ns}	0.57^{ns}	0.79^{ns}	0.63^{ns}	1.13^{ns}	1.04^{ns}	0.96^{ns}	0.86^{ns}
Variety	4.99^{ns}	8.04^{ns}	0.47^{ns}	0.49^{ns}	1.55^{ns}	0.90^{ns}	1.23^{ns}	0.26^{ns}	0.29^{ns}	2.38^{ns}	3.49^{ns}
Variety*Fertiliser	0.74^{ns}	0.94^{ns}	0.65^{ns}	1.18^{ns}	1.51^{ns}	0.59^{ns}	1.19^{ns}	1.06^{ns}	1.23^{ns}	0.98^{ns}	1.18^{ns}

Means followed by the same letter in a column are not significantly different at $P \leq 0.05$, ns means: non-significant at $P \leq 0.05$

Table 4.18: Effect of organic and inorganic fertiliser and their combination on protein content (%) of tomato grown at Apel and Horticultural centre (Mankweng)

Treatment	Apel	Mankweng
Variety		
Floradade	22.60a	18.84a
Moneymaker	20.57a	15.77a
Roma	19.60a	18.06a
Mean	20.92	17.56
Fertiliser type		
Control	20.36a	16.30a
NPK	20.65a	17.77a
Broiler manure	21.15a	17.73a
½ Broiler manure + ½ NPK	18.32a	18.58a
EM Compost	21.26a	17.71a
½ EM compost + ½ NPK	21.26a	16.92a
½ EM compost + ½ Broiler manure	21.10a	17.87a
Mean	20.92	17.56
F-values		
Fertiliser type	0.88^{ns}	1.78^{ns}
Variety	2.41^{ns}	4.89^{ns}
Variety*Fertiliser	1.37^{ns}	0.74^{ns}

Means followed by the same letter in a column are not significantly different at P ≤ 0.05, ns means: non-significant at P ≤ 0.05

4.4 Effect of organic and inorganic fertilisers on soil chemical composition of three tomato varieties

The chemical properties of the soil after experimentation are shown in Tables 4.19, 4.20, 4.21, and 4.22. The pH of the soil varied with treatments and location. At Apel the soil was alkaline in nature with pH ranging from 7.50 to 7.68 at 0-15 cm depth (Table 4.19) and 7.37 - 7.68 at 15 - 30 cm depth (Table 4.20). However, at Mankweng the pH of the soil was different from the one obtained in Apel. The soil showed to be acidic with the pH ranging from 4.17 to 5.69 at 0-15 cm depth (Table 4.21) and 4.21 to 5.66 at 15 - 30 cm depth (Table 4.22). Comparing the tomato varieties, at Apel the highest K content of 572 was obtained in Roma under NPK treatment while the least value (193) in Moneymaker under control treatment (Table 4.20). At Mankweng, the highest K value (328) was obtained in Roma under soil treated with ½ EM compost + ½ NPK, while the least value (64) was found in Moneymaker under soil treated with NPK (Table 4.22). Similarly, Roma variety had highest K value whereas Moneymaker had the lowest value at both sites (Apel and Mankweng).

Table 4.19: Soil chemical properties (0-15 cm depth) at the experimental site at harvest at Apel

Variety	Fertiliser type	%						mg kg^{-1}			
		N	Ca	Mg	K	P	Org. C	C	Zn	Cu	pH (KCl)
Floradade	Control	0.05	3496	1345	215	5	0.5	1.4	2.9	5	7.68
	NPK	0.10	3705	1273	299	26	0.9	3.8	3.3	7	7.59
	Broiler manure	0.14	3472	1190	378	13	1.0	2.0	3.2	14	7.58
	½ Broiler manure + ½ NPK	0.09	2727	1744	523	67	0.6	2.9	3.6	17	7.61
	EM Compost	0.05	3921	1127	305	5	0.5	1.7	3.0	5	7.64
	½ EM compost + ½ NPK	0.10	3414	1457	537	92	0.8	8.3	2.6	10	7.53
	½ EM compost + ½ Broiler manure	0.05	3406	1454	296	10	0.5	2.3	3.1	7	7.64
Money maker	Control	0.05	4109	1771	225	1	0.5	1.0	2.5	3	7.56
	NPK	0.08	3861	1576	566	39	0.6	3.2	3.3	7	7.57
	Broiler manure	0.06	4782	1674	268	7	0.8	3.4	3.5	9	759
	½ Broiler manure + ½ NPK	0.07	4042	1439	295	27	0.5	2.3	3.7	7	7.57
	EM Compost	0.05	10052	1470	341	5	0.5	1.5	2.9	3	7.50
	½ EM compost + ½ NPK	0.07	3303	1346	483	31	0.5	2.9	3.4	8	7.62
	½ EM compost + ½ Broiler manure	0.11	3917	1280	371	3	0.5	1.4	2.6	5	7.56
Roma	Control	0.05	3313	1318	269	4	0.7	1.2	2.7	4	7.62
	NPK	0.08	4034	1611	476	41	0.6	1.9	3.3	6	7.56
	Broiler manure	0.07	4169	1490	290	3	0.6	1.4	3.4	6	7.59
	½ Broiler manure + ½ NPK	0.06	3799	1569	427	46	0.5	2.8	3.7	10	7.55
	EM Compost	0.12	5430	1694	389	21	0.9	1.5	3.8	11	7.56
	½ EM compost + ½ NPK	0.07	10387	1427	435	38	0.5	4.3	3.5	7	7.59
	½ EM compost + ½ Broiler manure	0.12	4497	1695	255	5	0.5	1.5	3.2	6	7.52

Table 4.20: Soil chemical properties (15-30 cm depth) at the experimental site at harvest at Apel

Variety	Fertiliser type	%				mg kg^{-1}					
		N	Ca	Mg	K	P	Org. C	Zn	Cu	Mn	pH (KCl)
Floradade	Control	0.05	3718	1318	198	4	0.5	1.5	3.1	4	7.68
	NPK (Rec)	0.10	3922	1120	234	7	0.7	1.8	3.3	5	7.60
	Broiler manure(Rec)	0.17	3414	1457	322	6	1.3	1.2	3.1	13	7.52
	½ Broiler manure + ½ NPK	0.10	3705	1273	318	26	0.8	4.0	2.8	8	7.50
	EM Compost (Rec)	0.05	3572	1191	317	5	0.5	1.6	3.2	4	7.64
	½ EM compost + ½ NPK	0.05	2714	1457	373	11	0.7	4.2	3.2	11	7.62
	½ EM compost + ½ Broiler manure	0.05	2719	1741	222	5	0.5	1.2	3.1	6	7.68
Money maker	Control	0.05	4148	1557	193	1	0.5	0.9	2.5	3	7.55
	NPK (Rec)	0.05	5989	1602	460	36	0.5	1.9	3.5	7	7.56
	Broiler manure(Rec)	0.10	4367	1480	293	6	0.9	1.4	3.6	10	7.55
	½ Broiler manure + ½ NPK	0.10	8852	1369	250	24	0.5	2.0	3.2	5	7.56
	EM Compost (Rec)	0.05	3077	1266	218	2	0.5	1.3	2.8	3	7.62
	½ EM compost + ½ NPK	0.07	4198	1169	425	21	0.5	2.4	3.2	6	7.58
	½ EM compost + ½ Broiler manure	0.08	3775	538	316	1	0.5	0.9	2.4	5	7.50
Roma	Control	0.08	3915	1424	274	1	0.5	0.5	3.1	4	7.51
	NPK	0.06	4529	1757	572	83	0.5	3.0	3.3	8	7.57
	Broiler manure	0.08	4110	1490	303	4	0.5	1.2	3.7	9	7.58
	½ Broiler manure + ½ NPK	0.05	9812	1560	420	41	0.5	2.0	3.6	12	7.62
	EM Compost (Rec)	0.05	7913	1312	271	2	0.5	0.8	3.2	4	7.62
	½ EM compost + ½ NPK	0.05	4545	1745	390	41	0.5	3.6	3.7	8	7.51
	½ EM compost + ½ Broiler manure	0.11	3635	1521	345	4	1.0	2.1	3.1	6	7.37

Table 4.21: Soil chemical properties (0-15 cm depth) at the experimental site at harvest at Horticultural centre (Mankweng)

Variety	Fertiliser type	%						mg kg^{-1}			
		N	Ca	Mg	K	P	Org. C	Zn	Cu	Mn	pH (KCl)
Floradade	Control	0.07	678	72	168	162	1.0	36.0	31.2	22	4.17
	NPK	0.15	865	102	98	165	1.9	43.0	22.7	20	4.50
	Broiler manure	0.12	801	105	67	135	1.5	36.0	22.2	21	4.32
	½ Broiler manure + ½ NPK	0.11	886	113	194	105	1.6	29.0	16.8	21	4.80
	EM Compost	0.13	930	116	208	113	1.8	39.0	19.3	22	4.91
	½ EM compost + ½ NPK	0.14	737	88	240	132	20	34.0	21.5	28	4.62
	½ EM compost + ½ Broiler manure	0.12	1055	117	197	121	1.7	33.0	17.7	25	4.84
Money maker	Control	0.15	759	90	248	166	1.6	45.0	40.0	24	4.78
	NPK	0.07	817	97	289	182	1.1	38.0	29.0	26	4.84
	Broiler manure	0.11	732	99	326	122	1.6	31.3	22.6	20	5.32
	½ Broiler manure + ½ NPK	0.06	748	120	292	116	1.0	25.4	9.4	20	5.51
	EM Compost	0.14	847	120	425	166	1.7	42.0	42.0	23	5.33
	½ EM compost + ½ NPK	0.05	883	129	324	103	1.2	25.0	8.9	22	5.69
	½ EM compost + ½ Broiler manure	0.13	947	168	697	164	1.6	41.0	32.9	29	5.76
Roma	Control	0.12	903	119	196	151	1.6	41.0	25.1	25	4.69
	NPK	0.10	890	104	242	143	1.5	37.0	14.4	26	4.83
	Broiler manure	0.10	1125	113	168	164	1.4	34.0	17.2	24	5.08
	½ Broiler manure + ½ NPK	0.15	1056	129	230	164	2.0	45.0	22.9	22	4.80
	EM Compost	0.18	1057	116	242	154	2.7	41.0	16.0	21	5.00
	½ EM compost + ½ NPK	0.07	990	109	347	157	1.5	42.0	20.8	21	4.90
	½ EM compost + ½ Broiler manure	0.13	1062	141	279	155	1.8	47.0	30.2	22	5.08

Table 4.22: Soil chemical properties (15-30 cm depth) at the experimental site at harvest at Horticultural centre (Mankweng)

Variety	Fertiliser type	%						mg kg-1			
		N	Ca	Mg	K	P	Org. C	Zn	Cu	Mn	pH (KCl)
Floradade	Control	0.11	915	105	174	150	1.6	48.0	27.9	24	4.65
	NPK (Rec)	0.07	999	110	157	136	1.3	32.0	11.2	24	5.26
	Broiler manure(Rec)	0.15	1078	128	224	180	2.3	42.0	23.4	26	5.07
	½ Broiler manure + ½ NPK	0.12	1029	112	184	160	1.8	44.0	20.3	21	4.77
	EM Compost (Rec)	0.08	986	108	194	172	1.7	35.0	16.4	21	4.60
	½ EM compost + ½ NPK	0.12	993	117	232	182	1.8	46.0	28.8	23	4.52
	½ EM compost + ½ Broiler manure	0.12	1043	145	279	184	1.6	60.0	41.9	28	4.99
Roma	Control	0.05	747	75	163	191	0.9	48.0	60.0	25	4.34
	NPK (Rec)	0.10	778	83	241	178	1.4	48.0	36.0	31	4.36
	Broiler manure(Rec)	0.07	762	101	177	151	1.1	34.0	32.4	21	4.93
	½ Broiler manure + ½ NPK	0.06	788	98	270	103	0.9	22.5	10.1	24	5.11
	EM Compost (Rec)	0.07	810	114	208	89	1.2	28.8	17.0	21	5.14
	½ EM compost + ½ NPK	0.12	934	125	328	118	1.6	28.8	10.0	26	5.66
	½ EM compost + ½ Broiler manure	0.17	928	142	273	137	2.1	34.0	23.2	20	5.60
Money maker	Control	0.09	698	71	197	171	1.3	36.0	38.0	27	4.30
	NPK (Rec)	0.11	778	80	64	171	1.7	46.0	22.8	22	4.24
	Broiler manure(Rec)	0.10	795	102	165	136	1.3	31.0	27.5	24	4.21
	½ Broiler manure + ½ NPK	0.15	886	109	157	206	2.2	51.0	39.0	24	4.53
	EM Compost (Rec)	013	971	121	181	123	1.5	39.0	20.4	21	4.58
	½ EM compost + ½ NPK	0.13	1034	114	189	162	1.8	39.0	29.3	26	4.53
	½ EM compost + ½ Broiler manure	0.10	980	114	169	111	1.6	31.7	13.6	19	4.87

CHAPTER 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Tomato is one of the most popular and widely consumed vegetable crops all over the world because of its vital role in human diet and health. Investigation on the effect of sole and combined application of organic and inorganic fertilisers on growth, yield and nutritional qualities of popular varieties of tomato grown in Limpopo Province will be of immense benefit to smallholder farmers.

Application of different fertilisers materials (organic and inorganic) resulted in increased tomato plant growth. The three varieties differ in their responses to fertiliser treatments. For instance, at Apel the highest average plant height was obtained in Moneymaker grown in broiler manure treatment, for Floradade the highest average height was found in broiler manure and NPK treatment combination while that of Roma variety was found in EM compost and NPK treatment combination. Similar trend was also recorded at Mankweng.

The tomato varieties did not differ in their responses to fertiliser types in terms of fresh shoot, root and fruit masses. Although the dry masses differ in relation to variety, fertiliser type and location. At both sites the highest fruit masses were found in sole organic manure treatments. At Apel, it was found in Moneymaker grown under EM compost treatment, while at Mankweng, it was found in Roma grown under sole broiler manure treatment.

Response of tomato varieties in terms of nutritional composition and fertiliser application varied. For instance, at Apel, K, Zn, Mn and Fe contents of tomato varieties differ with fertiliser treatments. The highest average K content was found in tomato varieties grown in soil treated with ½ broiler manure + ½ NPK while the least value was obtained in the control. Similarly, highest mean Zn content was found in tomato grown in the same treatment, but the lowest average value was obtained in ½ EM + ½ NPK treatment. For Mn and Fe contents in tomato, highest mean values for Mn and Fe respectively were found in sole broiler manure treatment while the least values for Mn and Fe respectively were found in ½ EM compost + ½ NPK and sole NPK treatments, respectively.

In general, combined application of organic (broiler manure or EM-enriched compost) with inorganic (NPK) fertiliser had positive impact on tomato growth, yield and nutritional composition. Therefore, resource-poor smallholder farmers may apply such combinations to minimise input costs.

REFERENCES

ABDEL-MONAIM, M.F. (2012). Induced systemic resistance in tomato plants against Fusarium wilt diseases. *International Research Journal of Microbiology* 3: 14-23.

ABDUL, K., ABBASI, M.K., and HUSSAIN, T. (2006). Effects of integrated use of organic and inorganic nutrient sources with effective microorganism (EM) on seed cotton yield in Pakistan. *Bioresource Technology Journal* 97: 967- 972.

ADEDIRAN, A.J., TAIWO, B.L., AKANDE, O.M., SOBULE, A.R., and IDOWU, J.O. (2004). Application of organic and inorganic fertiliser for sustainable maize and cowpea yields in Nigeria. *Journal of Plant Nutrition* 27: 1163-1181.

ADEKIYA, A.O., and AGBEDE, T.M. (2009). Growth and yield of tomato (*Lycopersicon esculentum* Mill) as influenced by poultry manure and NPK fertilizer. Department of Agricultural Engineering Technology, Rufus Giwa Polytechnic, Owo, Ondo State, Nigeria. *Food Agricultural* 21: 10-20.

AGYEMAN, K., OSEI-BONSU, I., BERCHIE, J.N., OSEI M.K., MOCHIAH, M.B, LAMPTEY, J.N., OSEI, K., and BOLFREY-ARKU, G. (2014). Effect of Poultry Manure and Different Combinations of Inorganic Fertilizers on Growth and Yield of Four Tomato Varieties in Ghana. *Agricultural Science* 2: 27-34.

ANO, A.O., and AGWU, J.A. (2005). Effect of animal manures on selected soil chemical properties. *Nigerian Journal of Soil Science* 15: 14-19.

ARISHA, H.M.E., GAD, A.A., and YOUNES, S.E. (2003). Response of some pepper cultivars to organic and mineral nitrogen fertiliser under sandy soil conditions. *Zagazig Journal of Agricultural Research* 30: 1875 -1899.

ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS (AOAC). (2005). Official Method of Analysis. Washington DC.

AYOOLA, O.T. and ADENIYAN, O.N. (2006). Influence of poultry manure and NPK fertilizer on yield and yield components of crops under different cropping systems in south west Nigeria. *African Journal of Biotechnology* 5: 1386-1392.

BERGMANN, W. (1992). Nutritional disorders of plants. Germany. 100nd edition. Gustav Fischer Verlag, Jena

BLAY, E.T., DANQUAH, E.Y., OFOSU-ANIM, J. and NTUMY, J.K. (2002). Effect of poultry manure on the yield of shallot. *Advanced Horticultural Science* 16:13-16.

CAMBERATO, J. J. (2001). Nitrogen in Soil and Fertilizers. South Carolina Turfgrass Foundation 8: 6-10.

DEPARTMENT OF AGRICULTURE, FORESTRY and FISHERIES (DAFF). (2016). A Profile of the South African Tomato Market Value Chain. South Africa.

EZEAGU, I.E., PETZKE, J.K., METGES, C.C., AKINSOYINU, A.O., and OLOGHOBO, A.D. (2002). Seed protein contents and nitrogen-to-protein conversion factors for some uncultivated tropical plant seeds. *Food Chemistry* 78: 105-109.

FARMING SA and AGRICULTURAL RESEARCH COUNCIL, JANUARY. (2009). Vegetable Growing, Supplement to Farming SA.

GARG, S. and BAHLA, G.S. (2008). Phosphorus availability to maize as influenced by organic manures and fertilizer P associated phosphatase activity in soils. *Bioresource Technology Journal* 99: 5773-5777.

GERSTER, H. (1997). The potential role of lycopene for human health. *Journal of the American College of Nutrition* 16: 109-126.

HU, M., and QI, Y. (2013). Long-term effective microorganism's application promote growth and increase yields and nutrition of wheat in China. *European Journal of Agronomy* 46: 63-67.

HUE, N.V. (1995). Sewage Sludge. In: J.E. Rechcigl (ed) Soil amendment and environmental quality. Lewis Publishers, Boca Raton. FL, Pp 193-239.

ILUPEJU, E.A.O., AKANBI, W.B., OLANIYI, J.O., LAWAL, B.A., OJO M.A. and AKINTOKUN, P.O. (2015). Impact of organic and inorganic fertilizers on growth, fruit yield, nutritional and lycopene contents of three varieties of tomato (*Lycopersicon esculentum* (L.) Mill) in Ogbomoso, Nigeria. *African journal of biotechnology* 14: 2424-2433.

JOUBERT, G. (1974). The cultivation of vegetables in South Africa, the cultivation of root crops: the cultivation of beetroot. Root Crops Series No.A.1/1974. Horticultural Research Institute, Pretoria.

KAMANGA, S.C. (2013). Effect of organic and inorganic fertiliser on soil properties, striga density and maize yield in Vihiga and Siaya countries, Kenya. M.Sc. Thesis. Department of Land Resource Management and Agricultural Technology, University of Nairobi, Nairobi. Pp 12.

LEONARD, D. (1986). Soil, Crop, and Fertilizer Use: A Field Manual for Development Workers. Under contract with Peace Corps. 4th edition revised and expanded. United State Peace Corps. Information collection and exchange.

LONG ISLAND SEED PROJECT (LISP). (2011). Tomato description information. *www.Liseed.org* (accessed 2016/10/02)

MAHARISHNAN, K.A., SAMBASIRA, S., and BHANU, K. (2004). Effects of Organic Sources of plant Nutrients in conjunction with chemical fertilizers on growth, yield and quality of rice. *Research on Crops* 5:159-161.

MAKINDE, A.I., JOKANOLA, O.O., ADEDEJI, J.A., AWOGBADE, A.L., and ADEKUNLE, A.F. (2016). Impact of organic and inorganic fertilisers on the yield, lycopene and some minerals in tomato (*Lycopersicum esculentum mill)* fruit. *European Journal of Agriculture and Forestry Research* 4: 18-26.

MARSHNER, H. (1995). Mineral nutrition of higher plants. 2nd edition. Academic Press, San Diego, CA.

MBAH, C.N. (2006). Influence of organic wastes on plant growth parameters and nutrient uptake by maize (*Zea mays* L.). *Nigerian Journal of Soil Science* 16: 104-108.

MOHAMMAD, M., EBRAHIM, I.D., HOUSHANG, N., and AHMAD, T. (2013). Growth and yield of tomato (*Lycopersicon esculentum* Mill.) as influenced by different organic fertilisers. *International Journal of Agronomy and Plant Production* 4: 734-738.

MPANGANE, P.N.Z, AYISI, K.K, MISHIYI, M.G, and WHITBREAD, A. (2004). Grain yield of maize, grown in sole and binary cultures with cowpea and lablab in the Limpopo Province of South Africa. In Tropical Legumes for Sustainable Farming Systems in Southern Africa and Australia. ACIAR Proceedings 115: 106-114.

NATARAJAN, K. (2007). Panchagavya for plant. Proceedings of National Conference Glory Gomatha, Veterinary University, Tirupati,Pp 72-75.

NGEZE, P.B. (1998). Learn how to make and use compost manure in farming. Friend-of-the-Book Foundation, Nairobi, Kenya.

OBI, M.E, and EBO, P. (1995). The effect of organic and inorganic amendments on soil physical properties and production in a severely degraded sandy soil in southern Nigeria. *Bioresource Technology Journal* 51: 117-123.

OGUNDARE, S.K., BABALOLA, T.S., HINMIKAIYE, A.S., and OLONIRUHA, J.A. (2015). Growth and fruit yield of tomato as influenced by combined use of organic and inorganic fertiliser in Kabba, Nigeria. *European Journal of Agriculture and Forestry Research* 3: 48-56.

OUDA, B.A, and MAHDEEN, A.Y. (2008). Effects of fertiliser on growth, yield, yield components, quality and certain nutrient contents in Broccoli (*Brassica oleracea*). International *Journal of Agriculture and Biology* 10: 627-632.

OYEWOLE, C.I., and OYEWOLE, A.N. (2011). Crop production and the livestock industry, the interplay: A case study of poultry manure and crop production. Proceeding of the 16th Annual Conference of Animal Science Association of Nigeria,Pp 124-127.

PERRENOUD, S. (1993). Fertilizing for high Yield Potato. IPI Bulletin 8. International Potash Institute, Basel, Switzerland.

PIDWIRMY, M.J. (2002). Fundamentals of Physical Geography. Introduction to Biogeography and Ecology. The Nitrogen Cycle. 2nd Ed. British Columbia. Canada.

SREENIVASA, M.N., NAGARAJ, M.N., and BHAT S.N. (2010). BEEJAMRUTH: A source for beneficial bacteria. *Karnataka Journal of Agricultural Science* 17:72-77.

APPENDICES

Appendix 4.1: ANOVA table for the interactive effect of variety and fertiliser type on plant height (cm) of tomato grown at Apel AT 8 WAT

Source of variation	DF	SS	MS	F	P
Replication	3	1957.4	652.46		
Variety (V)	2	5507.2	2753.59	12.76	0.0069
Error REP*variety	6	1295.3	215.88		
Fertiliser type (F)	6	2696.8	449.47	2.15	0.0624
V x F	12	1469.7	122.48	0.59	0.8441
Residual	54	11292.3	209.12		
Total	83	24218.7			

Appendix 4.2: ANOVA table for the interactive effect of variety and fertiliser type on plant height (cm) of tomato grown at Horticultural centre (Mankweng) at 8 WAT

Source of variation	DF	SS	MS	F	P
Replication	3	3101.3	1033.77		
Variety (V)	2	3631.6	1815.80	9.13	0.0151
Error REP*variety	6	1193.3	198.88		
Fertiliser type (F)	6	672.2	112.04	1.11	0.3704
V x F	12	966.9	80.57	0.80	0.6524
Residual	54	5464.7	101.20		
Total	83	15030.0			

Appendix 4.3: ANOVA table for the interactive effect of variety and fertiliser type on dry shoot mass (g) of tomato grown at Mankweng at 12 WAT

Source of variation	DF	SS	MS	F	P
Replication	3	45598	15199.5		
Variety (V)	2	125887	62943.3	9.43	0.0140
Error REP*variety	6	40028	6671.3		
Fertiliser type (F)	6	27105	4517.6	2.87	0.0167
V x F	12	22837	1903.1	1.21	0.3003
Residual	54	84906	1572.3		
Total	83	346361			

Appendix 4.4: ANOVA table for the interactive effect of variety and fertiliser type on dry fruit mass (g) of tomato grown at Apel at 12 WAT

Source of variation	DF	SS	MS	F	P
Replication	3	9477.2	3159.06		
Variety (V)	2	499.0	249.51	0.89	0.4576
Error REP*variety	6	1676.3	279.38		
Fertiliser type (F)	6	3485.2	580.87	2.05	0.0751
V x F	12	4797.5	399.79	1.41	0.1909
Residual	54	15328.5	283.86		
Total	83	35263.6			