DETERMINATION OF YIELD AND YIELD COMPONENTS OF SELECTED TOMATO VARITIES IN SOIL WITH DIFFERENT LEVELS OF CATTLE MANURE APPLICATION

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DECLARATION

I declare that the dissertation hereby submitted to the University of Limpopo for the degree of Master of Agricultural Management (Crop Science) has not previously been submitted by me for a degree at this or any other University; that it is my work in design and in execution, and that all material contained in it has been duly acknowledged.

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K.G. MALEKA

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ABSTRACT

Organic tomatoes are increasingly popular with larger market acceptance since organic farming uses limited or no artificial chemicals. Application of organic fertilisers such as cattle manure has potential to boost organic tomato productivity particularly under low input farming systems. However, information is required on the optimum level of manure application on different tomato cultivars to help emerging tomato farmers in South Africa. The objective of this study was to determine the relative response of yield and yield components among selected determinate and indeterminate tomato cultivars using different levels of cattle manure. Two separate field experiments were conducted at the University of Limpopo during 2007 and 2008 using a split plot design with three replications. Two sets of tomato cultivars were included in which one set consisted indeterminate types (Money Maker, Ox Heart and Sweetie) and the other determinates (Roma and Floradade). Cultivars were assigned as the main plot treatments with six rates of manure (0, 10, 20, 30, 40 and 50 in gram per plant) applied as the subplot treatments to each set. Results indicated significant interactions ($P \leq 0.01$) between indeterminate tomato cultivars and levels of manure applied for fruit yield and fruit size in both experiments. Plant height showed variation from 78 to168 cm in Experiment I and 87 to 176 cm in Experiment II. During Experiment I fruit number varied from 23 to 91 per plant and 23 to 97 in Experiment II. Significant differences were detected among determinate cultivars on fruit yield varying from 7928 to 3 4705 kg per hectare during Experiment I and 3 169 to 2 9840 kg per hectare during Experiment II. Overall, the best level of manure for maximum fruit yield and greater fruit size was achieved at 40 g per plant in the indeterminate cultivar Sweetie. Conversely, the best level of manure for maximum fruit yield was achieved at 30 g per plant in determinate cultivar Roma. Thus, to achieve maximum yield, tomato growers could apply 600 and 800 kg per hectare manure on the determinate and indeterminate tomato cultivars, respectively.

CHAPTER 1

GENERAL INTRODUCTION

Tomato (*Lycopersicum esculentum Mill*.) is an essential component of human diet that supplies vitamins and minerals (Law-Ogbomo and Egharevba, 2008). It belongs to Solanaceae family, grown widely for its edible fruits. Tomato requires proper and sufficient nutrients for good fruiting and subsequent quality. Manure is a source of nitrogen, potassium and phosphorus, which are essential in South African soil. The use of cattle manure is a well established crop production practice under small scale farming in South Africa (Materechera *et al*., 2000). Cattle manure is easily accessible and is a cheap source of fertilisation to enable additional income for emerging farmers.

Use of organic manures to meet the nutrient requirements of a crop would be a valuable practice for sustainable agriculture. Organic manure improves the soil physical, chemical and biological properties along with conserving the moisture holding capacity and thus resulting in enhanced crop productivity and quality (Premsekhar and Rajashree, 2009).

The amount of nitrogen that is available to plants is influenced by nitrogen mineralisation - immobilisation processes (Sorensen and Jensen, 1995), soil type and properties (Van Veen and Kuikman, 1990). Soil pH regulates microbial activity and hence mineralisation of organic matter. Thus, successful application of manure to soil requires an understanding of the impact of manure addition on microbial characteristics of the soil (Pell, 1997).

Organically produced food have larger market acceptance since organic farming uses little or no artificial chemicals for production. New employment opportunities in farming, processing and related services are also evident in the growth of the organic crop production sector (Midmore and Dirks, 2003). Organic farming is environmentally friendly and organic foods retain natural flavour and they are safe to human health.

Tomato production can be enhanced using cattle manure. There is limited information on the optimum level of manure application using different varieties of tomato in South Africa. Detailed information is necessary on the quantity of manure to be applied on different varieties of tomatoes to improve yield and quality under organic farming. Therefore, the objective of this study was to determine the relative response of yield and yield components among selected determinate and indeterminate tomato varieties using different levels of cattle manure. Results of the study may assist to identify the optimum amount of cattle manure application to improve tomato productivity using a suitable determinate or indeterminate cultivar.

CHAPTER 2

LITERATURE REVIEW

2.1 Botanical description and classification of tomato

Tomato plants are vines, initially decumbent, typically growing six hundred centimetres or more above the ground if supported. Erect bush varieties have been bred that are generally three hundred centimetres tall or shorter. Indeterminate types are "tender" perennials, dying annually in temperate climates although they can live up to three years in a greenhouse in some cases. Determinate types are annual in all climates. Tomato plants are dicots, and grow as a series of branching stems, with a terminal bud of growing. When the tip eventually stops growing, whether because of pruning or flowering, lateral buds take over and grow into other, fully functional vines (Peet, 2008). Most tomato plants have compound leaves, and are called regular leaf (RL) plants. Initially tomato was placed in the genus *Solanum* by Linnaeus as *Solanum lycopersicum* L. However, in 1768 Philip Miller placed it in its own genus, and he named it *Lycopersicon esculentum* and the name came into wide use. Technically, the combination *Lycopersicon lycopersicum* (L.) would be more correct, but this name has hardly ever been used. Therefore, it was decided to conserve the well-known *esculentum*, making this the correct name for the tomato when it was placed in the genus *Lycopersicon*. However, genetic evidence (Peralta and Spooner, 2001) has now shown that, placement of the tomato in the genus *Solanum*, was correct.

2.2 Climatic requirements of tomato

High temperature, high humidity and diseases at fruit setting lead to low yield in tomatoes (Ma, 1985). For optimum fruit setting, tomato requires night temperatures of 15-20^{o}C (Samaratunga, 1987). However, in lowlands, heat tolerant cultivars are needed especially in summer (Samaratunga, 1987). These cultivars with heat tolerance often need to be moisture tolerant (Samaratunga, 1987). At present there are modern tomato cultivars which can be grown to produce fruit in climates far different from the site of origin (Abubakar and Majeed, 2000).

2.3 Nutritional quality of tomato

The chemical composition and content of nutrients that are important for the human diet determine the nutritional quality of tomato. The amount of nutrients taken up by tomato depends on the number of fruit and the amount of dry matter produced (Hedge and Srinivas, 1990). This is influenced by the number of genetic and environmental variables (Shukla and Naik, 1993). Generally, the proportion of total nutrients found in tomato fruit declines with an increase in the level of nutrients applied (Hedge and Srinivas, 1990). Hegde and Srinivas (1990) found that 45.8 - 59.2% N, 56.5 - 63.6% of P and 62 - 69.6% of K partitioned into the fruit after partitioned total nutrient uptake into different plant parts of tomato. The stem contained the lowest proportion of N and P, while the leaf contained the lowest proportion of K. Varieties which take long to mature require more nutrients than short maturity groups mainly because of their higher production of dry matter and fruit (Shukla and Naik, 1993).

The uptake of manure nutrients in tomato depends upon soil moisture condition (Hedge and Srinivas, 1990). Nutrient uptake declines with increasing soil moisture stress (Hedge and Srinivas, 1990). Tomatoes yield higher when cattle manure is applied in winter for spring tomato production because decomposition would have taken place already (Oikeh and Asiegbu, 1993). When manure is applied in spring for spring tomato production little may happen because more time is needed for manure to be broken down before nutrients are released and made available for plant uptake (Shukla and Naik, 1993). Release of manure nutrients occur over a long time and during this period of winter for spring tomato production increasing quantities of plant nutrients become available to the crop (Shukla and Naik, 1993).

2.4 Nature of tomato fruit quality

Quality is defined as the sum of all characteristics that makes a consumer satisfied with the product (Harker *et al*., 2003). It is the most important consideration in tomato production to fetch high market price and achieve profit by growers. Quality includes fruit size, taste, appearance, flavour and firmness. Appearances are referred to as colour, shape and defects free (Kader, 1986). The impact of volatile compounds on flavour is determined by both their concentration and their odours (Baldwin *et al*., 2000). Some of these volatiles impart desirable qualities while others are negatively perceived (Baldwin *et al*., 2000). Baldwin *et al*. (1995) stated that flavour of tomatoes is determined by the sugar and acid composition of the fruit. Various aroma volatiles combine to give typical tomato-like aroma and flavour (Baldwin *et al*., 1995).

2.5 Factors affecting fruit quality of tomato

2.5.1 Dry matter content

High dry matter or low water content of tomato has been reported to affect fruit taste positively because the major components of tomato taste, sugar and acids are more concentrated (Guichard *et al*., 2001). In organic fruit and vegetable production, increased dry matter content was related to a slower growth due to shortage of the organically bound nutrients in the fertiliser (Hagland *et al*., 1997). However, higher dry matter can be achieved in a conventional production as well, when water uptake is reduced (Guichard *et al*., 2001) e.g. by increasing the electrical conductivity of nutrient solution through high fertilisation rate (Satti *et al.,* 2001).

2.5.2 Temperature

Exposures to improper temperatures severely lead to loss of quality in tomato. Tomato fruit exposed to a shorter duration of low temperatures is prone to storage problems (Kader, 1986). Chilling temperatures lead to injury and loss of flavour (Kader, 1986). Lack of colour uniformity, softening and tomato fruit diseases are the result of exposure to chilling temperature of tomato (Rozin, 1999). For optimum fruit setting, tomato requires night temperatures of 15-20^{o}C (Rozin, 1999). However, in lowlands, heat tolerant cultivars are needed especially in summer. Such cultivars with heat tolerance often need to be moisture tolerant (Samaratunga, 1987).

2.5.3 Nutrient and water supply

Cultural practices such as nutrient and water supply are major factors influencing quality of tomato (Winter and Rushbrook, 2003). Highest demand for water is during flowering. Water deficit during the flowering period causes flower drop which leads to yield loss (Winter and Rushbrook, 2003). However, moderate water deficit during the vegetative period enhances fruit number and size (Winter and Rushbrook, 2003). Withholding irrigation during this period is also recommended to force less mature plants into flowering in order to obtain uniform flowering and ripening (Winter and Rushbrook, 2003).

2.6 Major production constraints of tomato

The practice of continuous monoculture increases the possibility and severity of pest and disease epidemics leading to yield reduction (Dong *et al*., 2003). Increase in soil acidity increase the severity of diseases and reduce the availability of nutrients and activity of soil microbes (Rowel, 1994; Franzoi, 1996). Most of the farmer use chemicals pest management method and they apply chemicals once every two weeks. Many regimes of chemical applications lead to development of resistance without eliminating crop natural enemies leading to damages to the crop (Dong *et al*., 2003).

2.7 Role of cropping systems on growth and development of tomato

Rye and hairy vetch reduce the need for inputs such as fertilisers and pre-emergence herbicides in tomato production (Masiunas *et al*., 1995; Abdul-Baki *et al*., 1996). Sperry *et al*. (1996) found that rye cover crop mulch systems changed the vegetable crop micro environment by reducing soil temperatures and increasing soil surface moisture, which influenced crop growth and yield (Masiunas *et al*., 1997; Bottenberg *et al*., 1999). Total tomato yields in cover crop mulch systems have been found to be higher than those using in conventional tillage, but often fruit maturity is delayed (Masiunas *et al*., 1995; Abdul-Baki *et al*., 1996;). The delayed tomato fruit maturity in some rye mulch systems was likely due to lower soil temperatures and nitrogen immobilisation (Masiunas *et al*., 1995). The amount of fruit cracking, concentration of organic acids, and colour intensity may be some of the specific quality factors affected by the microenvironment changes occurring in rye mulch systems. Cracking usually occurs during the last phase of fruit growth (Bakker, 1988; Sperry *et al*., 1996; Peet, 2008). Rye mulch systems also increase moisture near the soil surface and reduce fluctuations in moisture (Bottenberg *et al*., 1999). Soil water availability affects tomato fruit quality (Ram, 2000; Dumas *et al*., 2003).

2.8 Sustainable agricultural production

Sustainable agriculture is “the ability of farming systems to continue into the future”. This implies that sustainable agriculture means a “maintenance of the adaptive capacity of farming systems” (Park and Seaton, 1996), enabling the future generations to meet their food demands. Sustainable agriculture has multiple-dimensional characteristics that include economic, environmental and social aspects (Legg, 1999; Pretty and Hine, 2001). In sustainable agriculture, organic farming is being promoted because of the positive environmental, social and economic impacts (Legg and Viatte, 2001).

Agricultural production in organic systems depends on the functions performed by soil microbial pools, particularly in nutrient supply (Smith *et al*., 1993). Organic farming has been spreading at an annual rate of ca. 20% in the last decade (Lotter, 2003), covering over 24 million hectares worldwide (Willer and Yussefi, 2004). Organic farming promotes soil structure formation (Pulleman *et al*., 2003), enhances soil biodiversity (Doles *et al*., 2001; Mäder *et al*., 2002; Oehl *et al*., 2004), alleviating environmental stresses (Horrigan *et al*., 2002; Macgilwain, 2004) and improving food quality and safety (Reganold *et al*., 2001; Giles, 2004). Organic farming advocates the use of organic and biological inputs for controlling diseases and pests and for nutrient supply (Rigby and Cáceres, 2001; Watson *et al*., 2002).

2.9 Organic farming

Organic farming is the form of agriculture that excludes or strictly limits the use of synthetic fertilisers, pesticides and plant growth regulators. Organic farming systems fall into similar categories as those of conventional agriculture: mixed, livestock, stockless and horticultural system (Berry *et al*., 2002). It is internationally regulated and legally enforced by many nations, based on the standards set by the International Federation of Organic Agriculture Movements. Organic farming combines scientific knowledge of ecology and modern technology with traditional farming practices based on naturally occurring biological processes (IFOAM, 2006). Organic farming mainly depends on intercropping and crop rotation methods to manage soil fertility. Application of compost and animal manure also contribute to subsequent soil fertility management (IFOAM, 2006).

2.10 Organic farming methods

2.10.1 Intercropping

Intercropping is the agricultural practice of cultivating two or more crops in the same space at the same time (Bizikova *et al*., 2007). The most common goal of intercropping is to produce a greater yield on a given piece of land by making use of resources that would otherwise not be utilized by a single crop (Altieri, 1994). The growing of two or more crops together has the potential to improve resource use (Boller and Hani, 2004). Several effective intercrop combinations have been developed demonstrating the opportunity to increase the use of symbiotically fixed nitrogen (Jansson, 1996; Bulson *et al*., 1997). Sowing of clover into cereals is a common practice for establishing ley (Taylor *et al*., 2001). Studies of intercropping vegetables and fertility building crop have indicated that competition between crop and legume can be a major problem (Carruthers *et al*., 1997; Lots *et al*., 1997). Even if intercropping increases soil nutrients, optimum level of manure is required (Bizikova *et al*., 2007).

2.10.2 Crop rotation

Crop rotation is a system where different plants are grown in a recurring, defined sequence (Berry *et al.*, 2002). It is the main mechanism for nutrient supply within organic systems (Berry *et al.*, 2002). Rotations also minimise the spread of weeds, pests and diseases (Altieri, 1994). The development and implementation of well-designed crop rotations is central to the success of organic production systems (Lampkin, 1990; Stockdale *et al*., 2001). Organic rotations are divided into phases that increase the level of soil nitrogen and phases that deplete it (Altieri, 1994). The nitrogen building and depleting phases must be in balance, or show a slight surplus, if long-term fertility is to be maintained (Berry *et al*., 2002; Bizikova *et al*., 2007). This type of rotation provides the basis for forward planning of nitrogen supply, necessary in the absence of soluble nitrogen fertiliser (Berry *et al.*, 2002). The fertility building phase of rotation usually takes the form of a ley, from one to five years in length, which incorporate a legume usually in combination with grass (Lampkin, 1990). Atmospheric nitrogen fixed by the legume-rhizobium symbiosis is made available to subsequent cash crops when the ley is incorporated and the nitrogen mineralised through the action of soil micro organisms. A typical rotation on mixed organic farm with three years grass and clover ley support two to three years of arable cropping (Lampkin, 1990). This may be extended by including a nitrogen fixing cash crop or by including a short period of nitrogen fixing green manure such as vetch (Stockdale *et al*., 2001). In order to make maximum use of the large quantity of nitrogen release following ley incorporation, crops with a high demand for nitrogen, such as winter wheat is usually grown at the start of the cropping phase (Lampkin, 1990). The amount of nitrogen decreases with time following incorporation of ley (Whitemore *et al*., 1992), thus spring sown cereals are often placed later in the arable phase of the rotation due to their lower nitrogen demand (Taylor *et al*., 2001).

2.11 Types of organic manure

Organic manures can be applied to soils as compost or in their fresh state. According to Cambardella *et al*. (2003), fresh organic materials contain higher inorganic N concentrations and have higher net N mineralisation rates than composted manure. Paul and Beauchamp (1994) reported that plants treated with organic manures exhibited higher dry matter in the first growing season than fresh manure.

2.11.1 Compost

Compost is a living culture, a colony of macro and micro organisms that convert organic matter into humus (Abbasi *et al*., 2002). Compost amendments play an important role in reducing economic losses from diseases in tomatoes especially in organic production systems. However, numerous compost quality parameters must be considered to provide consistent effects against root diseases (Hoitink and Boehm, 1999; Abbasi *et al*., 2002). Organic farmers often use composts as soil amendments, particularly in intensive vegetable production systems, to improve soil fertility, quality and sustain productivity (Dick and McCoy, 1993; Maynard, 1994; Workneh and van Bruggen, 1994). Composts improve biological, chemical, and physical properties of amended soils (Ndayegamiye and Cote, 1989). Furthermore, composts incorporated into soil or planting mixes provide effective biological control of diseases caused by soil borne plant pathogens (Hardy and Sivasithamparam, 1991; Chellemi *et al*., 1992; Gamliel and Stapleton, 1993). They also reduce the severity of diseases caused by foliar plant pathogens (Workneh and van Bruggen, 1994; Miller *et al*., 1997). It was shown that composts may improve the ability of plants to resist diseases caused by root as well as foliar pathogens by inducing systemic resistance in plants (Han *et al*., 2000). The components of composts responsible for this induced activity are biological or chemical in nature (Zhang *et al*., 1998). Resistance induced by plant activators such as actigard has been shown to be as effective as fixed copper sprays in reducing the incidence and severity of bacterial spot and speck in both fresh market and processing tomatoes (Ryals *et al*., 1994; Görlach *et al*., 1996; Louws *et al*., 2001).

2.11.2 Animal manure

In Africa, animal manure is applied to soil for fertility related issues and its benefits are well documented. Nutrient content in animal manure differs because of the variations in diet of the animals, collection and storage. Manure and other waste products of livestock have been used as soil amendments for decades and were the only ways of enhancing soil productivity before mineral fertilisers were invented (Lupwayi *et al*., 2000). Goat, sheep, cattle and chicken manure are the common manures used in the southern African regions with cattle contributing two thirds of the total amount of manure found and the remainder is contributed by sheep and goats manure.

2.12 Use of organic manure

Use of organic manures at agronomic rates for plant nutrient supply and for beneficial effects on soil physical properties is a traditional agricultural practice (Haynes and Naidu, 1998). Over the last decade the effects of organic manures on soil properties have received renewed attention due to an increased interest disposal of large amounts of waste being generated.

2.13 Nutrient composition of manure

Manure is a good source of macro- and micro nutrients thus it is an important nutrient disposal method (Madison *et al*., 1995). These contribute to diminishing the environmental pollution from manure disposal (Cooley *et al*., 2003). Manure contains all nutrients that plants need and is high in potassium and relatively low in phosphorus and nitrogen (Olkowski, 1995). Phosphorus and nitrogen are the two most deficient nutrients in manure (Oikeh and Asiegbu, 1993). Tourte (1997) stated that even if manure is high in potassium and relatively low in phosphorus and nitrogen, more manure can be applied to meet nitrogen and phosphorus needs of the crops (Tourte, 1997).

2.14 Role of manure on yield and yield components of crops

Tomato quality is assessed by the content of chemical compounds such as brix, acidity, soluble sugars, citric acids and other organic acids (Oikeh and Asiegbu, 1993). Total soluble solids (TSS) content of tomato fruit increase with optimal application of manure (Oikeh and Asiegbu, 1993). Manure lower in potassium reduces sugar content of tomato fruit (Tourte, 1997). Increasing rates of nitrogen in manure yield small tomato fruit and as a result increase in juice content. High rates of nitrogen in manure tend to decrease total soluble solids (Oikeh and Asiegbu, 1993). Fruit size also increases with high nitrogen than fruit with low nitrogen (Olkowski, 1995). Cattle manure with adequate nitrogen increases fruit size of tomato (Tourte, 1997). Adequate nitrogen fertilisation helps in increasing desirable acidic flavour (Oikeh and Asiegbu, 1993). The addition of manure does not only increase crop yields, it also increases the concentration of macronutrients in plant tissue (Sommerfeldt and Mackay, 1987). Tourte (1997) stated that optimum application of manure produce excellent fruit numbers, diameters, weights and total fruit yields of tomato. Motavalli *et al*. (1989) reported that uptake of N, P and K by plants increases with increasing rate of manure.

2.15 Role of organic soil fertility amendments on tomato leaf blight and soil microbial communities

Chemical control can be expensive and is not completely effective because of the clumped distribution of inoculums and resilient nature of *Sclerotia*. However, cultural control methods have been used to manage tomato leaf blight, and these include deep chisel tillage, application of mulches and soil solarisation (Ristaino *et al*., 1996). Mulches limit disease incidence by creating a physical barrier that prevents inoculum contact with the aboveground portions of the plant. Solarisation with clear plastic mulch has also been used to reduce sclerotia survival at shallow soil depths (Ristaino *et al*., 1991). Bio-control agents such as *Trichoderma harzianum* and *Gliocladium virens* also can affect southern blight development. These organisms reduce propagule densities of *Sclerotia rolfsii* in field soils and reduce the disease under controlled environment conditions (Papavizas and Collins, 1990; Mukherjee and Raghu, 1997). Solarisation in combination with application of bio control agents has also been effective in reducing diseases (Ristaino *et al*., 1996). Many of the sandy coastal plain soils in eastern North Carolina used for vegetable production are low in organic matter and the use of composted animal wastes or plant-derived composts and mulches could increase the organic matter content of the soil (Doran, 1995). Environmental concerns, including overflow of liquid effluent from hog lagoons and fish kills in nearby rivers, has led scientists and growers to seek alternative uses for the animal wastes (Burkholder *et al*., 1997; Mallin *et al*., 1997). Animal wastes provide an important under-utilized source of organic nutrients for plants and could be used to suppress plant disease (Hoitink and Boehn, 1999). There are several previous reports that have demonstrated that composted animal and plant wastes can suppress diseases caused by soil borne pathogens, including *Sclerotium rolfsii* (Hadar and Gorodecki, 1991; Canullo *et al*., 1992). Composts have been used in potting media to suppress soil borne pathogens (Gorodicki and Hadar, 1990; Hadar and Gorodecki, 1991). Corky root caused by *Pyrenochaeta lycopersici* was controlled much better under organic production than in fields under conventional production (Drinkwater *et al*., 1995).

2.16 Organic pests, diseases and weed control

Recommended beneficial insects include minute pirate bugs, big-eyed bugs, and ladybugs which eat a wide range of pests (Louws *et al*., 2001). Techniques for controlling weeds organically have varying levels of effectiveness and include hand weeding, mulch, corn gluten meal, flame, application of garlic and clove oil, borax, pelargonic acid, soil solarisation application of vinegar, and various other homemade remedies (Louws *et al*., 2001). One recent innovation is to introduce ducks and fish to wet paddy fields which eat weeds (Louws *et al*., 2001).

2.17 Contribution of organic agriculture to household nutrients intake

Organic agriculture contributes to hunger and poverty alleviation by diversifying and optimising farm productivity, reducing the need for purchased inputs and, eventually, developing households' market-orientation for earning additional income. Improved income allows farmers to buy food in what would otherwise be "hungry months" (Byerlee and Alex, 2005). Harnessing the lucrative gains that come from marketing organic commodities allow seasonal or permanent diversification away from staples into high-value alternatives such as vegetables, depending on the degree of physical and human capital investment and agro-ecosystem flexibility (Cano *et al*., 2003). Organic school and home gardens that cultivate traditional plants offer a promising option for improving the nutritional status of poor people both in rural and peri-urban areas. Such systems greatly contribute to food availability, safety of children and nutritional status of families (Byerlee and Alex, 2005).

2.18 Impact of organic farming on labour and rural development

Agricultural employment remains a source of social and ecological wellbeing of global importance (Colman, 2000; Shepherd and Pierce, 2003). Replacement of agricultural labour with chemicals and machinery raises concerns about social stability (Pretty, 2002; Soil Association, 2003). Agriculture is the main employer in rural areas and wage labour provides an important source of income for the poor. Thus, by being labour intensive, organic agriculture creates not only employment but improves returns on labour, including also fair wages and non-exploitive working conditions. Organic agriculture revitalizes rural economies and facilitates their integration into national economies. In several settings, it increases control over resources, develops self-awareness and collective self-help which lead to overcoming marginalization. Increasingly, organic agriculture is being adopted as a rural development strategy and vibrant organic communities are observed in rural areas of many countries. Soil Association (2006) reported that organic farms provide more than 30% more jobs ha^{-1} than non-organic farms and, thus, create employment opportunities. This ratio is further increased if on-farm processing and direct marketing are considered, because such enterprises are more likely fostered in organic systems. More recently researchers have turned their attention to the role of organic farming in the rural economy and specifically, the potential for organic farming to contribute to rural development (Pugliese, 2001). Organic farming promotes employment in rural areas and this contributes to rural development, for instance, through the provision of environmental services that underpin rural tourism (Hird, 1997; Midmore and Dirks, 2003).

2.19 Organic agriculture for local food provisioning

In agriculture-based economies, insufficient farming income translates into lack of sufficient purchasing power to pay for food and imported goods. Trade reform can be damaging to food security in the short to medium term if it is introduced without a policy package designed to offset the negative effects of liberalization (Thomas, 2006). For developing countries, trade-based food provisioning limits the competitiveness of smallholders and the ability of the market-marginalised to provide for their needs. Considering that two quarters of the poor live on the land and most are farmers or farm workers, it is in small holder agriculture where change is needed to increase the food supply. Factors that contribute to stagnating domestic production are low output prices, high input costs, adverse weather, pest and disease outbreaks, and consumer preference (FAO, 2007). Poor farmers often live in areas where there are few employment alternatives and agricultural inputs are limited. Thus organic agriculture can be considered as a unique alternative for local food provisioning provided that agro-ecological knowledge is available. Sustainable intensification of available natural resources in subsistence-oriented regions has proven to increase smallholders' food self-reliance and, eventually, decrease national food import requirements. Organic agriculture offers advantages in terms of enhancing food production where it is most needed by decreasing dependence on external inputs and increasing agro-ecosystem performance. A modelling for large-scale organic conversion in sub-Saharan Africa (Halberg *et al*., 2006) suggests that agricultural yields would grow by 50%, thus increasing local access to food and reducing food imports.

Organic agriculture is also an opportunity to commercialise small holder agriculture. A market oriented food system, if available, offers additional income generating opportunities that allow small producers to compete through the quality of their product while encouraging local food supply. Higher organic prices reflect production cost and internalise environmental and social values. Higher food prices also increase food import bills and may compromise low-income food buyers in the short run; however, higher food prices represent higher incomes to producers, with positive implications on longer term economic growth and agricultural development.

2.20 Benefits of organic agriculture as a climate change adaptation

Organic agriculture addresses key consequences of climate change, namely increased occurrence of extreme weather events, increased water stress (drought) and problems related to soil quality (Eyhorn, 2007). First, organic agriculture comprises highly diverse farming systems and thus increases the diversity of income sources and the flexibility to cope with adverse effects of climate change and variability, such as changed rainfall patterns. This leads to higher economic and ecological stability through optimized ecological balance and risk-spreading. Second, organic agriculture is a low-risk farming strategy with reduced input costs and, therefore, lower risks with partial or total crop failure due to extreme weather events or changed conditions in the wake of climate change and variability (Eyhorn, 2007). As such, it is a viable alternative for poor farmers. In addition, higher prices can be realized for the products via organic certification. High farm incomes are thus possible due to lower input costs and higher sale prices.

Organic agriculture is an adaptation strategy that can be targeted at improving the livelihoods of rural populations and those parts of societies that are especially vulnerable to the adverse effects of climate change and variability (Eyhorn, 2007). By its systemic character, organic agriculture is integrative approaches to adaptation, with potential to work toward the United Nations Millennium Development Goals to eradicate extreme poverty and ensure environmental sustainability. Organic agriculture addresses many of the key challenges identified for adaptation to climate change and variability (Slater *et al*., 2007).

2.21 Role of organic agriculture as a mitigation strategy on climate change

Organic agriculture as a mitigation strategy addresses both emissions avoidance and carbon sequestration through lower N_2O emissions. It is usually assumed that one to two percent of the nitrogen applied to farming systems is emitted as N_2O, irrespective of the form of the nitrogen input. The default value currently used by the Intergovernmental Panel on Climate Change (IPCC) is 1.25%, but newer research found considerably lower values. There is usually less erosion in organic farming systems (Renwick *et al*., 2004) and lower CO_2 emissions from organic farming system than in conventional ones. The "organic agriculture community" is aware of the potential of organic agriculture for climate change adaptation (Borron, 2006; IFOAM, 2006). Organic agriculture is linked to other proposals for adaptation, as it is, for example, an "adaptive social protection" strategy, as recently promoted by the Institute of Development Studies (Borron, 2006). In particular, organic agriculture has the best premises to utilise local and indigenous farmer knowledge and adaptive learning, which are seen as important sources for adaptation in farming communities (Tengö and Belfrage, 2004; Stigter *et al*., 2005; Salinger *et al*., 2005; Nyong *et al*., 2007; Niggli *et al*., 2008). Organic agriculture has all the aspects of optimal strategies that could address the challenges and goals for agriculture in the context of development and climate change (Rosenzweig and Tubiello, 2007; World Bank, 2008). Soil carbon sequestration is enhanced through agricultural management practices, which promote greater soil organic matter content and improves soil structure (Kotschi and Müller-Sämann, 2004; IFOAM, 2006; Niggli *et al*., 2008). Increasing soil organic carbon in agricultural systems has also been pointed out as an important mitigation option (Kotschi and Müller-Sämann, 2004).

2.22 Organic agriculture as a right-based to food security

The human-rights-based approach to food security offers new ways of identifying, analysing and solving the problems that underlie hunger and poverty, as well as an alternative method of promoting development (Nadia El-Hage Scialabba, 2007). A rights-based approach provides the powerless with leverage to address the causes of food insecurity and poverty. It strengthens local communities to take care of their own members. Besides its market pull, organic agriculture upgrades traditional knowledge through interactive learning, strengthening farmers' analytical abilities and creativity. Organised rural communities stand-up for their rights and extend entrepreneurial skills. In doing so, organic management revitalise indigenous knowledge and community structures which have eroded for a variety of reasons (e.g. land alienation, population pressure, migration) and empowers social systems to control their own food supply. Furthermore, organic agriculture is in line with the right to adequate food that consumers demand (Nadia El-Hage Scialabba, 2007).

2.23 Organic farming systems as a vehicle to improve energy efficiency

The high degree of reliance of conventional farming systems on cheap energy became a pressing concern in the wake of rapidly growing oil demand energy (Pimentel, 2006). The largest and most readily measured differences are associated with the energy required to manufacture, ship, and apply pesticides and nitrogen-based fertilizers (Pimentel *et al*., 2005). In calculating the total energy expended in major crop production on the farm, the additional energy expended by workers who mined and refined the oil, plus that of the workers who made the tractors and other farm equipment, are typically not included (Pimentel, 2006).

2.24 Nutritional value of organic farming

Organically grown crops have reportedly more vitamin C than conventionally grown products. The levels of some phenolics are lower than is optimal for human health in conventionally grown foods (Amy *et al*., 2002). Phenolic compounds were found significantly higher in organic foods and are generated by a plant when attacked by pests (Schreinemachers, 2000). Organic foods provide antioxidant protection against heart disease and cancer (Amy *et al*., 2002). A high antioxidant intake has been shown to be associated with a reduced incidence of coronary heart disease and some cancers. Such antioxidants include certain vitamins (vitamin E and beta-carotene) and substances known as phenolics (Charlier, 2003). On average, organic food contains higher levels of vitamin C and essential minerals such as calcium, magnesium, iron and chromium (Schreinemachers, 2000). An independent review of the evidence found that organic crops had significantly more percentages of all nutrients analysed compared with conventional produce including vitamin C (27% high), magnesium (29%), iron (21%) and phosphorous (14%). Organic spinach, lettuce, cabbage and potatoes showed particularly high levels of minerals (Charlier, 2003). There is growing evidence that organic fruit and vegetables generally contain more nutrients than non-organic food (Thiruchelvam, 2000). Generally, organic crops are not protected by pesticides and research has shown that organically produced fruit contains higher levels of phenolic compounds than conventionally grown fruit. It is reported that organic crops contain 10 to 50% more antioxidants than conventional crops (Alavanja, 2003).

2.25 Comparative advantages of organic farming

Conventional farming is unsustainable, because it relies on artificial inputs that ultimately require energy in the form of fossil fuels. It also leads to land degradation through soil erosion, salinisation, and other processes that eventually render the soil infertile. Without cheap fossil fuels and government subsidies, conventional agriculture would not be possible, and that despite technological advancements, there will eventually be an agricultural crisis as a result of depleted soil (Pimentel, 2006). The cultivation of monocultures increases susceptibility to pests and diseases and depletes the soil, while eliminating most native flora and fauna (Pimentel, 2006). Conventional agricultural practices often result in large amounts of nitrogen runoff from the heavy use of fertiliser, which pollutes watersheds. Pesticide runoff also causes many problems (Pimentel, 2006). In contrast, organic farming often utilises intercropping, crop rotation, fallow periods, and integrated pest management to promote biodiversity and preserve the health of the soil while minimising the risk of diseases. Organic farms seek to minimise dependence on outside resources and be self-sufficient.

2.26 Productivity and profitability of organic farming

Organic farms have higher pre-harvest yields than conventional counterparts in developing countries. Badgley *et al*. (2007) reported that organic crops yield 91% more than conventional crop. Conventional tomato production systems require extensive inputs of fertilisers, pesticides, and water to maintain yields and quality (Amy *et al*., 2002). Lotter (2003) reported that repeated organic farms withstand severe weather conditions better than conventional farms. Organic farming yield 70-90% more than conventional farms during droughts (Badgley *et al*., 2007). Lal (2004) reported that organic farming produces the same as conventional methods over the long-term averages, but consumed less energy and used zero pesticides. A study of 1,804 organic farms in Central America hit by Hurricane Mitch in 1998 found that the organic farms sustained the damage much better, retaining 20 to 40% more topsoil and smaller economic losses at highly significant levels than conventional farming (Halberg *et al*., 2006). The results were attributed to lower yields in general but higher yields during drought years. On the other hand, a 21-year Swiss study found an average of 20% lower organic yields over conventional, along with 50% lower expenditure on fertiliser and energy, and 97% less pesticides (Morris and Hopkin, 2001).

Organic farming build up soil organic matter better than conventional farming, which suggests long-term yield benefits from organic farming. Organic farming requires no synthetic fertiliser and pesticides. The decreased costs on those inputs, along with the premiums which consumers pay for organic produce, create higher profits for organic farmers (Badgley *et al*., 2007).

2.27 Institutional and financial aspects of organic agriculture

The importance of adequate institutional frameworks and financial management for adaptation has frequently been pointed out (Kandlikar and Risbey, 2000; Smit and Skinner, 2002). Regarding the institutional framework, organic agriculture can, in principle, build on the existing general agricultural institutions present in any country and internationally. However, a main hindrance is the fact that organic agriculture is not yet broadly recognized for its potential as a development strategy and even less as an adaptation or mitigation strategy. In particular, its capability to produce yields high enough to replace conventional agriculture to a significant amount is often questioned. In organic agriculture, prospects for long-term sustained productivity are a given and are different from many intensive conventional farming systems, where, after some decades, decreasing yields are observed (Matson *et al*., 1997). Specialized institutions for organic agriculture such as International Federation of Organic Agricultural Movement (IFOAM) have the crucial task of spreading the knowledge about organic agriculture. Organic agriculture as an adaptation and mitigation strategy does not hinge on large additional financing for the organic agriculture farming system itself. However, it is crucial to have access to international markets and to develop local markets for the products. In the transition phase to organic agriculture, additional financing for the farms may be necessary: training and extension services need to be provided and lower yields for the two to three years of the transition period may necessitate some additional support. The economic viability of organic farming is also likely to increase with increasing energy prices, which makes conventional farming more expensive, due to the energy costs for production of fertilisers and pesticides, and with decreasing levels of subsidies for conventional agriculture. Several options to meet the financial requirements exist in principle. Examples are governmental support and research programs for agriculture, microfinance strategies and biodiversity conservation initiatives (Carroll *et al*., 2007)

2. 28 Molecular makers as a tool to support yield stability in organic agriculture

Molecular markers are an additional value in an approach that departs from a holistic view when results are converted to the level of farming and processing practices. Besides, molecular markers would assist in selection for quantitative traits in organic farming, as there is still a gap between phynotyping and genotyping of crops (Backes and Ostergard, 2008; Xu and Crouch, 2008). Markers approach would provide the tool to breed for a complex trait, such as nutrient use efficiency in a more efficient way to maximise yield. Molecular assistant selection is able to improve the introgression of exotic and wild alleles and thereby increase genetic diversity in the pool of available varieties.

Molecular assisted selection helps to overcome selection with pyramiding of resistance source for late blight which is very difficult to achieve without molecular markers (Tan, 2008). *Phytopthora* infestation is a threat for organic agriculture, so resistance varieties would improve the position in organic agriculture (Lamments van Bueren *et al*., 2008; Vos, 2009). Achieving varieties adapted to low input agriculture is one of the molecular makers' strategy to optimise yield stability and good quality in organic agriculture. The low input management of organic agriculture results in a larger influence of varying environmental conditions in time and geographically on crop performance. To cope with varying environmental condition, adaptive and robust variety is required (Lamments van Bueren *et al*., 2002; Wolfe *et al*., 2008). Specific for organic agriculture, low inputs farming methods is the needs for adapted plant architecture above and below ground resulting in improved weeds competitiveness and nutrient use efficiency (Mason and Spanner, 2006; Ostergard *et al*., 2007). Traits such as nutrient use efficiency are quantitative traits largely influenced by environment and management.

The efficiency of the breeding and selection process to improved performance of varieties in organic farming can be assessed in many different ways including the ultimate success of the varieties released and the frequency with which new varieties are produced. Large breeding programs for annual crops may carry hundreds of thousands of lines to produce a new variety only once every few years. Field trials can be expensive and evaluation of some traits, such as quality and yield stability can be expensive to assess. Molecular markers have proved to be a powerful tool in replacing bioassays and there are now many examples available to show the efficacy of markers to better the yield of varieties for organic farming (Langridge and Chalmers, 2004).

CHAPTER 3

YIELD AND YIELD COMPONENTS RESPONSE OF SELECTED INDETERMINATE AND DETERMINATE TOMATO VARIETIES UNDER DIFFERENT LEVELS OF CATTLE MANURE APPLICATION

3.1 INTRODUCTION

Low soil fertility threatens the security of yield in South Africa farming. It is a major overriding constraint that affects all aspects of crop production (Mbah, 2006). The use of inorganic fertilizer is not helpful in agriculture because is unaffordable and associated with reduced crop yield and yield components (Ojeniyi, 2000).

Organic agriculture contributes to poverty alleviation to poor South African farmers by reducing the need for purchased inputs, hence earning additional income (Byerlee and Alex, 2005). Profit emerged from marketing organic commodities allow diversification from staples into high-value alternatives vegetables (Cano *et al*., 2003). Organic agriculture greatly contributes to food availability and nutritional status of families (Byerlee and Alex, 2005).

The benefits of using cattle manure have not been fully utilized, partly due to the huge quantities required to satisfy the nutritional needs of crops (Ayoola and Adeniyan, 2006). High and sustained crop yield could not be obtained, because of injudicious and imbalanced manure application.

For South African to secure high yield, use of cattle manure is advocated for tomato production to improve low inherent fertility of soils (Agbede *et al*., 2008). Large quantities of organic manure are available especially in rural areas and are an effective source of nutrients for varieties of tomato (Adediran *et al*., 2003). The crop yield response to manure is highly variable and depends on the level of manure and varieties of tomato (Adediran *et al*., 2003).

Organically grown tomatoes are increasingly popular and have larger market acceptance since organic farming uses little or no artificial chemicals for production. Application of organic fertilisers such as cattle manure has a potential of boosting organic tomato productivity particularly under low input farming systems. However, optimum level of manure application on different varieties of tomato remains a challenge to emerging farmers in South Africa. Thus, the objective of this study was to determine the relative response of yield and yield components among selected determinate and indeterminate tomato varieties using different levels of cattle manure.

3.2 MATERIAL AND METHODS

3.2.1 Description of the study area

The experiments were conducted in Limpopo Province, at the University of Limpopo's Experimental Farm (Syferkuil). The farm is situated at approximately 10 km North West of Mankweng (29^{o} 71' S, 23^{o} 84' E). The experimental farm is characterised by hot dry summer and cool dry winters. The long-term annual rainfall on the experimental farm is 468.4 mm. The mean average day temperature varies from 28 ^{o}C to 30 ^{o}C. The soil at the farm was sandy loam soil of Hutton form, Glenrosa family, with the pH ranging from 6.0-6.2.

3.2.2 Experimental design, treatments and procedures

Two independent field experiments were conducted under irrigation. The first experiment was carried out during September to December 2007. To confirm the results of this trial a second set of study was carried out during September to December 2008. The experiments were laid out in a split plot design with three replications using two sets of experiments. One set consisted three indeterminate (Money Maker, Ox-Heart and Sweetie) and the other two determinate (Roma and Floradade) tomato cultivars that were assigned as the main plot treatments. Six different levels of manure in gram per plant (0, 10, 20, 30, 40 and 50) were applied to each set as subplot treatments. Spacing was 1 m (inter row) and 0.5 m (intra row) corresponding to approximately 20 000 plants per hectare. During planting manure was manually incorporated and hoed in the soil around the base of each plant. Figure 3.1 shows established tomato plants during early flowering stage of the experiment.

3.2.3 Data collection

During the experiment data were collected from ten randomly selected sample plants per plot. Plant height was measured in centimetres at 50% flowering from the base to the tip of the plant using a measuring tape. Fruit size was measured in millimetres from six random fruit samples using a hand held fruit calliper during first harvests. Fruit number was manually counted per plant during harvesting. Fruit yield was measured in gram per plant and converted into kilograms per hectare at the end of harvests. Total soluble solids (in percentage) were measured by a hand held refractometer after harvest. Prior and after experiments, soil analyses were conducted to determine the major plant nutrients including N, P, K, Ca and Mg. Surface (0-15 cm) soil samples were taken over each side before start of experiments. For manure and soil nutrient analyses, samples were bulked and air dried. After the experiment, representative samples were taken for analysis as described by Carter (1993). Organic matter (OM) was determined by Walkley-Black dichromate digestion method (Nelson and Sommer, 1982) and total soil nitrogen was determined by the Kjeldah method (Bremner and Mulvancy, 1982). Available P was determined using the Bray-1 method and exchangeable K, Ca and Mg were extracted using ammonium acetate. Potassium was determined on a flame photometer and Ca and Mg by EDTA titration. The soil pH was determined using glass electrodes.

Figure 3.1 Tomato plants during early flowering stage of the experiment at Syferkuil, University of Limpopo

3.2.4 Data analysis

Data were subjected to analysis of variance (ANOVA) using Agrobase (2005). Traits that showed significant differences from the ANOVA were further subjected to the Least Significant Difference (LSD) test procedure and mean comparison was made at 5% probability level of significance. The degrees of relatedness between the dependent and independent variables were expressed as R – square values from each ANOVA. The coefficients of variation (CV) were computed and expressed as percentages (Snedecor and Cochran, 1989). Correlation analyses were performed to describe the pattern of association between plant height, fruit size, fruit number, total soluble solids and fruit yield.

3.3 RESULTS

3.3.1 Results on agronomic characteristics of indeterminate tomato cultivars

The analyses of variances for various characters during both experiments are indicated in Appendix 6.1 to 6.20. Results of each trait are presented from section 3.3.1.1- 3.3.1.5,

3.3.1.1 Plant height

During Experiment I plant height showed variation among cultivars and level of manure only (Appendix 6.1). However, there were significant interactions ($P \leq 0.01$) between tomato cultivars and levels of manure applied on plant height during Experiment II (Appendix 6.2). Results showing the average plant heights of tomato cultivars against the six levels of manure during both experiments are summarised in Table 3.1. In Experiment II, the best record of interactions was 176 cm with the application of 40 g manure on cultivar Ox-Heart. In Experiment I the best levels of manure that rendered increased average plant height (157 cm) were 40 or 50 g per plant (Table 3.1). Low levels of manure rendered reduced plant height. Cultivar Ox-Heart responded relatively better with a plant height of 138 cm compared to Money Maker (134 cm) and Sweetie (124 cm). There were no statistical significant interactions among cultivars and manure applications on plant height. But increased plant height (168 cm) was noted for cultivars Ox-Heart and Money Maker when 40 or 50 g manure was applied (Table 3.1). In general, both studies showed that application of 40 g per plant would provide increased plant height (Figure 3.2). Plant height should have significant effect on subsequent flowering and fruit yield in tomato especially in the indeterminate cultivars.

Table 3.1 Mean plant height (cm) of three indeterminate tomato cultivars tested using six levels of manure over two experiments

Manure (g/plant)	Experiment I				Manure (g/plant)	Experiment II			
	Cultivar					Cultivar			
	Money Maker	Ox Heart	Sweetie	Mean		Money Maker	Ox Heart	Sweetie	Mean
0	103.00	105.00	87.33	98.44	0	88.67	87.00	78.33	84.67
10	114.33	117.33	104.67	112.11	10	115.67	112.33	105.33	111.11
20	127.33	129.00	125.00	127.11	20	120.33	126.67	112.67	119.89
30	143.67	144.33	130.67	139.56	30	126.33	145.00	114.67	128.67
40	147.33	168.33	154.67	156.56	40	137.00	176.33	119.33	144.22
50	167.67	162.33	139.67	156.78	50	136.00	160.33	115.33	137.22
Mean	133.89	137.72	123.67	131.76	Mean	120.67	134.61	107.61	120.96
$LSD_{0.05}$ Cultivar = 5.39 $LSD_{0.05}$ Manure = 7.62 $LSD_{0.05}$ Cultivar x Manure = 13.20						$LSD_{0.05}$ Cultivar = 4.13 $LSD_{0.05}$ Manure = 5.84 $LSD_{0.05}$ Cultivar x Manure = 10.12			

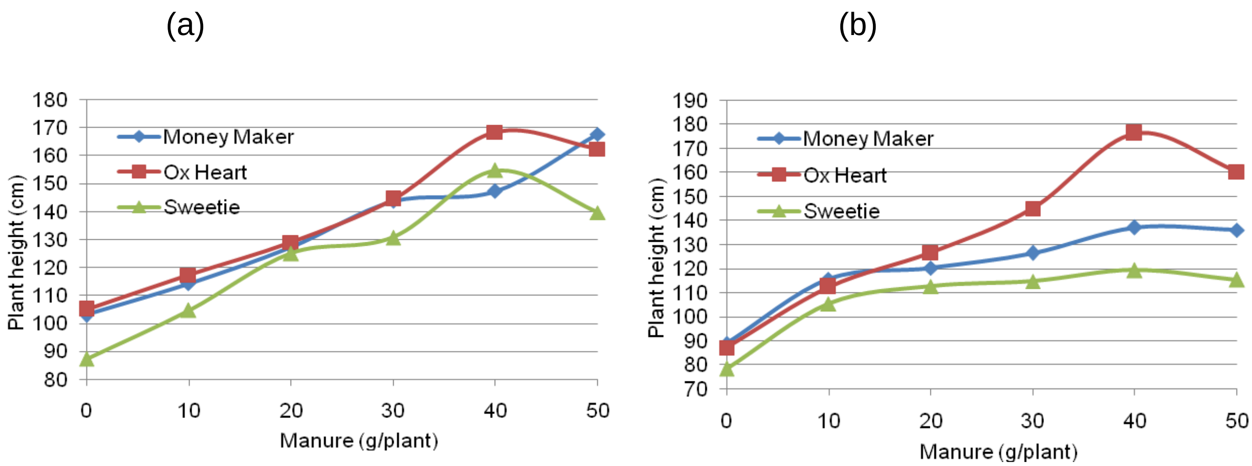

Figure 3.2 Mean responses of plant height at different levels of manure applications in three indeterminate tomato cultivars during Experiments I (a) and II (b)

3.3.1.2 Fruit size

There were significant interactions (P < 0.01) between tomato cultivars and levels of manure applied for fruit size in both Experiments I and II (Appendices 6.3 and 6.4). Table 3.2 summarised the mean fruit size of tomato cultivars against six levels of manure. Fruit size ranged from 28 to 81 mm in Experiment I and 25.33 to 90.00 mm in Experiment II. The best interactions (81 and 90 mm) were recorded for cultivar Money Maker at 50 g per plant of manure in both Experiments I and II. (Table3.2.). The best levels of manure for larger fruit size (72 and 75 mm) were achieved at 40 g per plant of manure in both Experiments I and II, respectively (Table 3.2). Cultivar Money Maker had larger fruit size (65 mm), followed by Ox Heart (57 mm) and Sweetie (51 mm) in Experiment II. In general the maximum fruit size was achieved at 40 g/plant of manure (Figure 3.3). Cultivar Money Maker had increased fruit size than Ox Heart and Sweetie even at 50 g manure.

Table 3.2 Mean fruit size (mm) of three indeterminate tomato cultivars tested using six levels of manure over two experiments

Manure (g/plant)	Experiment I Cultivar				Manure (g/plant)	Experiment II Cultivar			
	Money Maker	Ox Heart	Sweetie	Mean		Money Maker	Ox Heart	Sweetie	Mean
0	28.33	47.67	36.67	37.56	0	25.33	28.00	25.33	26.22
10	53.33	58.00	54.00	55.11	10	51.67	49.67	42.67	48.00
20	64.33	60.33	62.67	62.56	20	65.67	61.00	55.67	60.78
30	73.67	63.00	66.00	67.56	30	75.00	66.00	56.33	65.78
40	80.67	64.33	72.33	72.44	40	82.00	77.00	68.33	75.78
50	81.33	60.00	61.67	67.67	50	90.00	59.00	58.00	69.00
Mean	63.61	58.89	58.89	60.46	Mean	64.94	56.78	51.06	57.59
$LSD_{0.05}$ Cultivar = 2.80 $LSD_{0.05}$ Manure = 3.96 $LSD_{0.05}$ Cultivar x Manure = 6.86						$LSD_{0.05}$ Cultivar = 3.46 $LSD_{0.05}$ Manure = 4.91 $LSD_{0.05}$ Cultivar x Manure = 8.49			

(a) (b)

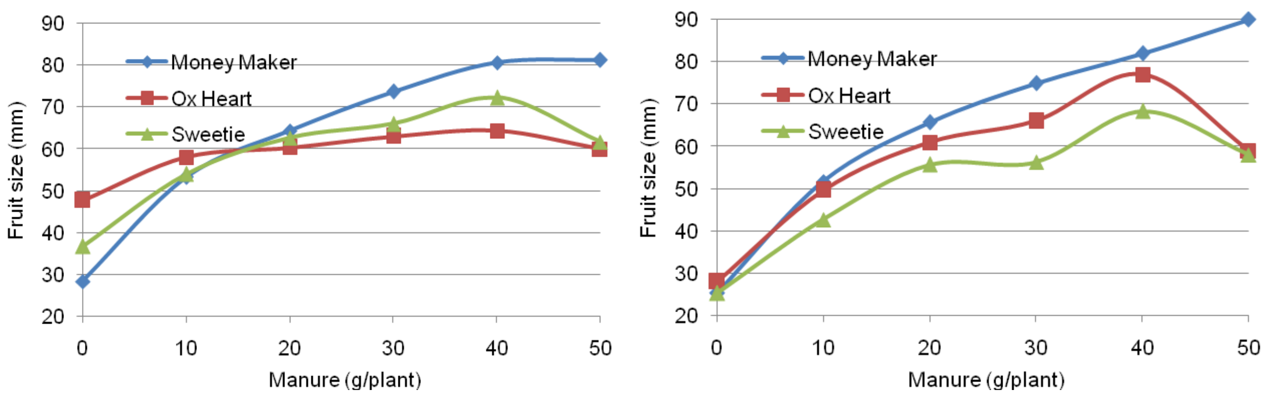

Figure 3.3 Mean responses of fruit size at different levels of manure applications in three indeterminate tomato cultivars during Experiments I (a) and II (b)

3.3.1.3 Fruit number

Fruit number varied among cultivars and levels of manure in Experiment I (Appendix 6.5). Nevertheless, there were significant interactions ($P \leq 0.05$) between tomato cultivars and levels of manure applied on fruit number in Experiment II (Appendix 6.6). The best level of manure with increased average fruit number at 72 and 81 per plant were produced at 40 g per plant during Experiments I and II, respectively (Table 3.3). Cultivar Ox-Heart responded relatively better with 68 fruits compared to Money Maker (58) and Sweetie (52). Higher level of interactions (97 fruit) was obtained for cultivar Ox Heart at 40 g of manure application. There were no statistical significant interactions among cultivars and manure applications on fruit number in Experiment I. However, increased fruit number (91) was evident for cultivar Ox-Heart when 40 g manure applied (Table 3.3). In general, both studies showed that application of 40 g manure per plant would provide increased fruit number using cultivar Ox-Heart (Table 3.3). Figure 3.4 indicates that the optimum level of manure to achieve higher fruit number is at 40 g per plant. Cultivar Ox-Heart is the best in bearing several fruits (90-95) per plant in both studies.

Table 3.3 Mean fruit number of three indeterminate tomato cultivars tested using six levels of manure over two experiments

Manure (g/plant)	Experiment I Cultivar				Manure (g/plant)	Experiment II Cultivar			
	Money Maker	Ox Heart	Sweetie	Mean		Money Maker	Ox Heart	Sweetie	Mean
0	23.33	35.33	31.33	30.00	0	25.67	30.33	23.00	26.33
10	46.00	62.33	51.67	53.33	10	38.33	63.33	49.00	50.22
20	60.67	69.33	61.33	63.78	20	50.67	77.67	63.00	63.78
30	69.33	78.33	57.00	68.22	30	63.67	82.67	70.00	72.11
40	76.67	90.67	48.00	71.78	40	71.00	97.00	76.00	81.33
50	69.33	72.00	60.00	67.11	50	54.33	85.00	79.67	73.00
Mean	57.56	68.00	51.56	59.04	Mean	50.61	72.67	60.11	61.13
$LSD_{0.05}$ Cultivar = 6.53 $LSD_{0.05}$ Manure = 9.24 $LSD_{0.05}$ Cultivar x Manure = 16.01						$LSD_{0.05}$ Cultivar = 3.80 $LSD_{0.05}$ Manure = 5.37 $LSD_{0.05}$ Cultivar x Manure = 9.31			

(a) (b)

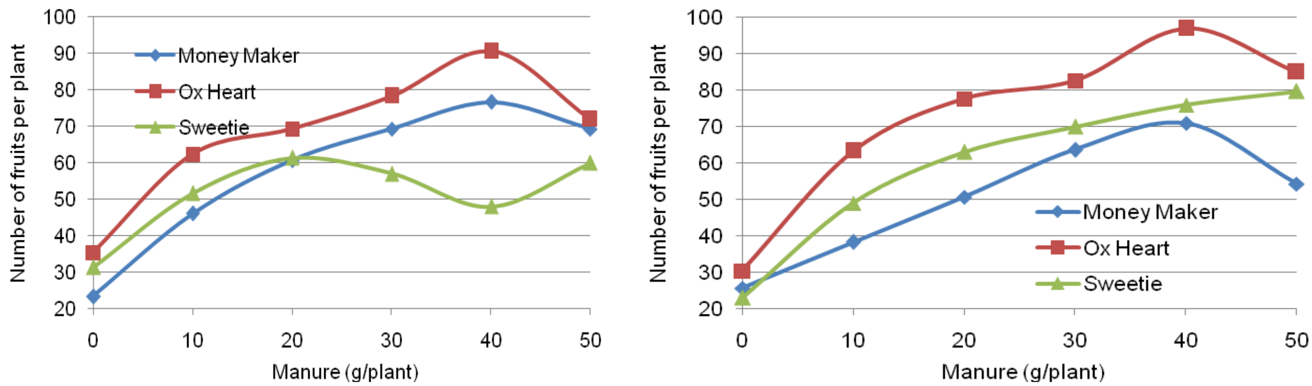

Figure 3.4 Mean responses of fruit number at different levels of manure applications in three indeterminate tomato cultivars during Experiments I (a) and II (b)

3.3.1.4 Total soluble solids

Cultivars had differences in total soluble solids (TSS) due to differences in the levels of manure applied during Experiment I (Appendix 6.7). The best levels of manure for maximum average TSS (8%) were at 40 or 50 g per plant (Table 3.4). In Experiment II total soluble solids showed variations due to differences among cultivars and levels of manure applied (Table 3.4). Analysis of variance showed no significant interactions between tomato cultivars and levels of manure applied for total soluble solids in both Experiments I and II (Appendix 6.7 and 6.8). However, increased total soluble solids (10%) were recorded at 40 g per plant using cultivar Ox Heart in Experiment II (Table 3.4). Ox Heart displayed total soluble solids between 5.67 to 8.67% TSS in Experiment I and 4.33 to 10.33% TSS in Experiment II. Sweetie had 6 to 7.33% TSS in Experiment I and 3.67 to 8% TSS in Experiment II (Table 3.4). The best level of manure for highest percent of total soluble solids was achieved at 40 g per plant (Figure 3.5).

Table 3. 4 Mean total soluble solids (%) of three indeterminate tomato cultivars tested using six levels of manure over two experiments

Manure (g/plant)	Experiment I Cultivar Money Maker	Ox Heart	Sweetie	Mean	Manure (g/plant)	Experiment II Cultivar Money Maker	Ox Heart	Sweetie	Mean
0	6.00	5.67	6.00	5.89	0	5.00	4.33	3.67	4.33
10	6.00	6.00	6.00	6.00	10	6.33	5.33	5.33	5.67
20	6.33	6.33	6.00	6.22	20	8.00	6.67	6.33	7.00
30	7.33	6.67	6.67	6.89	30	8.00	7.33	7.00	7.44
40	7.67	8.67	7.00	7.78	40	8.67	10.33	7.67	8.56
50	8.00	8.00	7.33	7.78	50	9.33	8.33	8.00	8.89
Mean	6.89	6.89	6.50	6.76	Mean	7.56	7.06	6.33	6.98
$LSD_{0.05}$ Cultivar = 0.59 $LSD_{0.05}$ Manure = 0.84 $LSD_{0.05}$ Cultivar x Manure = 1.46						$LSD_{0.05}$ Cultivar = 0.62 $LSD_{0.05}$ Manure = 0.86 $LSD_{0.05}$ Cultivar x Manure = 1.51			

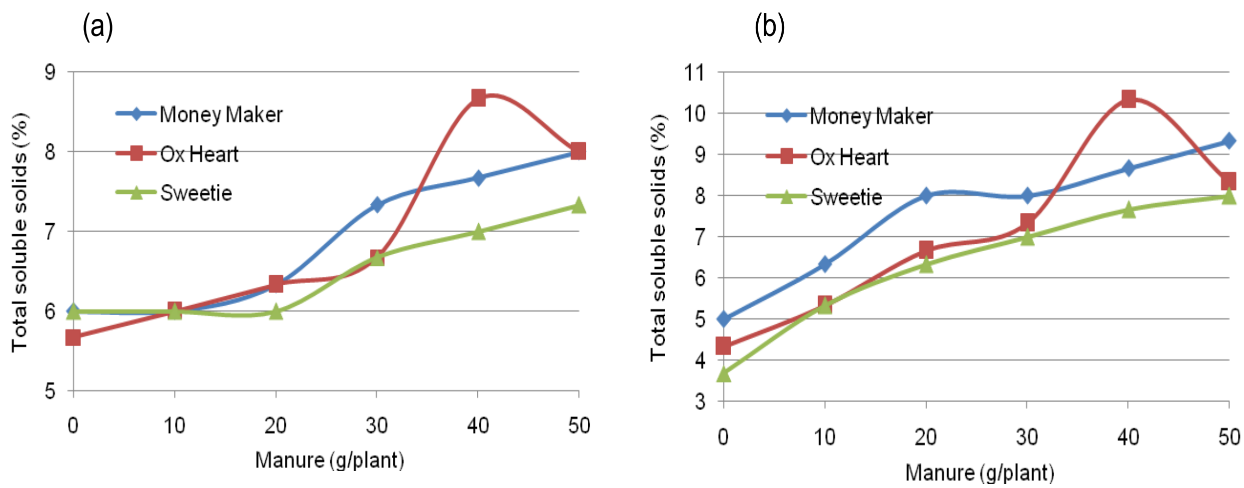

Figure 3.5 Mean responses of total soluble solids at different levels of manure applications in three indeterminate tomato cultivars during Experiments I (a) and II (b)

3.3.1.5 Fruit yield

Results indicated that there were significant interactions ($P < 0.01$) between tomato cultivars and level of manure applied on fruit yield in both Experiments I and II (Appendices 6.9 and 6.10). Table 3.5 shows the mean responses of cultivars against six levels of manure applied on fruit yield. On average, the best (42 052 and 38830 kg/ha) was observed for cultivar Sweetie when 40 g per plant of manure was applied in both Experiments I and II respectively (Table 3.5). During the first experiment reduced fruit yields of cultivar Sweetie (9 689 kg/ ha) was observed with no manure application. Cultivar Ox Heart displayed fruit yields of 10 453 to 38 636 kg per hectare in Experiment I and 10 255 to 38 103 kg per hectare in Experiment II. The best level of manure for maximum fruit yields (39 350 and 38 054 kg/ha) were achieved at 40 g per plant using cultivar Sweetie in Experiments I and II, respectively (Table 3.5). In both Experiments I and II cultivar Money Maker recorded the maximum average yields of 31 097 and 30 728 kg/ha, respectively. Overall, highest fruit yield was achieved at 40 g per plant of manure (Figure 3.6). Thus, application of 40 g manure per plant could be regarded as the economic optimum for tomato production. First harvests during the experiment are shown in Figure 3.7.

Table 3.5 Mean fruit yield (kg/ha) of three indeterminate tomato cultivars tested using six levels of manure over two experiments

Manure (g/plant)	Experiment I				Manure (g/plant)	Experiment II			
	Cultivar					Cultivar			
	Money Maker	Ox Heart	Sweetie	Mean		Money Maker	Ox Heart	Sweetie	Mean
0	7311	10453	9689	9151	0	8447	10255	11063	9922
10	31515	22685	20057	24752	10	29975	26220	30425	28873
20	34940	25562	23700	28067	20	33371	19232	35907	29503
30	36148	37023	35379	36183	30	36481	34422	37512	36138
40	37363	38636	42052	39350	40	37228	38103	38830	38054
50	39304	6544	22790	22879	50	38864	35270	30484	24292
Mean	31097	23484	25611	26730	Mean	30728	21960	30704	27797
$LSD_{0.05}$ Cultivar 3164 $LSD_{0.05}$ Manure = 4474 $LSD_{0.05}$ Cultivar x Manure = 7750						$LSD_{0.05}$ Cultivar = 2430 $LSD_{0.05}$ Manure = 3436 $LSD_{0.05}$ Cultivar x Manure = 5952			

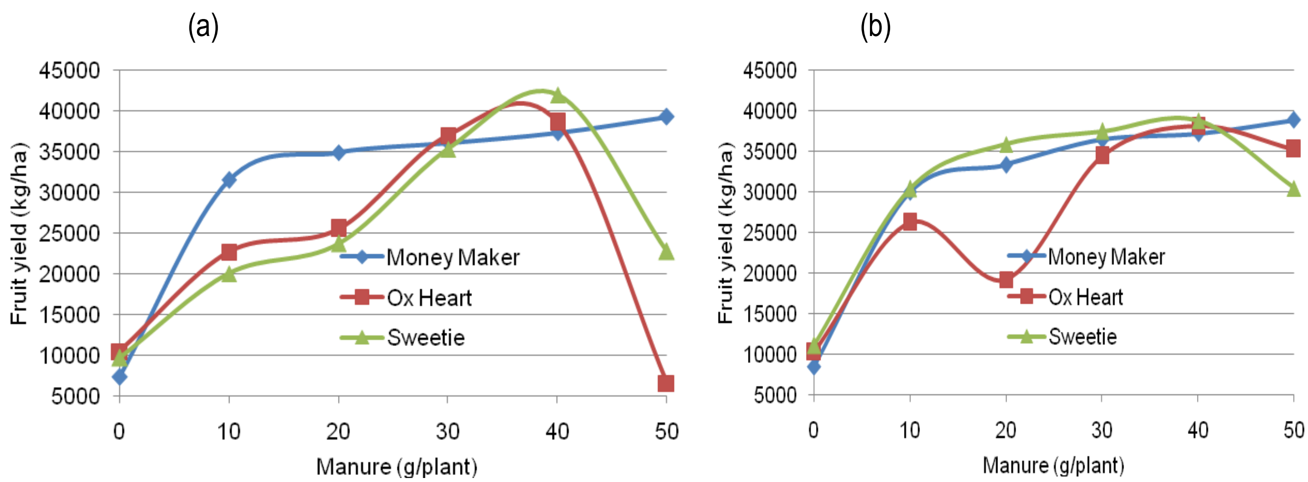

Figure 3.6 Mean responses of fruit yield at different levels of manure applications in three indeterminate tomato cultivars during Experiments I (a) and II (b)

Figure 3.7 First harvests of tomato fruit during the experiment at Syferkuil, University of Limpopo

3.3.2 Results on agronomic characteristics of determinate tomato cultivars

Results of both experiments showing yield and yield components of determinate tomato varieties when tested using various levels of manure applications are presented in sections 3.3.2.1 to 3.3.2.5

3.3.2.1 Plant height

Significant differences were detected among tomato cultivars and levels of manure applications (Appendices 6.11 and 6.12). Cultivar Floradade had maximum plant height of 62 and 64 cm during Experiments I and II, respectively. There were no significant interactions between cultivars and manure levels on plant height in both Experiments I and II (Appendices 6.11 and 6.12). Nonetheless, tallest plant heights (93 and 96 cm) were observed at 50 gram per plant of manure in cultivar Floradade in both Experiments I and II (Table 3.6). Plant height ranged from 35.67 to 82.33 cm in Experiment I and 34 to 80.67 cm in Experiment II in cultivar Roma. Floradade had plant height that ranged from 37.67 to 93.33 cm and 31 to 96.33 cm during Experiments I and II, respectively. The best level of manure for maximum plant height was noted at 50 g per plant (Figure 3.8).

Table 3.6 Mean plant height (cm) of two determinate tomato cultivars tested using six levels of manure over two experiments

Manure (g/plant)	Experiment I Cultivar Roma	Floradade	Mean	Manure (g/plant)	Experiment II Cultivar Roma	Floradade	Mean
0	35.67	37.67	36.67	0	34.00	31.00	32.50
10	45.67	46.33	46.00	10	45.00	48.33	46.67
20	51.33	54.67	53.00	20	53.67	57.33	55.50
30	60.67	66.33	63.50	30	64.67	70.67	67.67
40	66.67	73.33	70.00	40	69.00	80.00	74.50
50	82.33	93.33	87.83	50	80.67	96.33	88.50
Mean	57.06	61.94	59.50	Mean	57.83	63.94	60.88
$LSD_{0.05}$ Cultivar = 2.47 $LSD_{0.05}$ Manure = 4.28 $LSD_{0.05}$ Cultivar x Manure = 6.05					$LSD_{0.05}$ Cultivar =3.73 $LSD_{0.05}$ Manure = 6.46 $LSD_{0.05}$ Cultivar x Manure = 9.13		

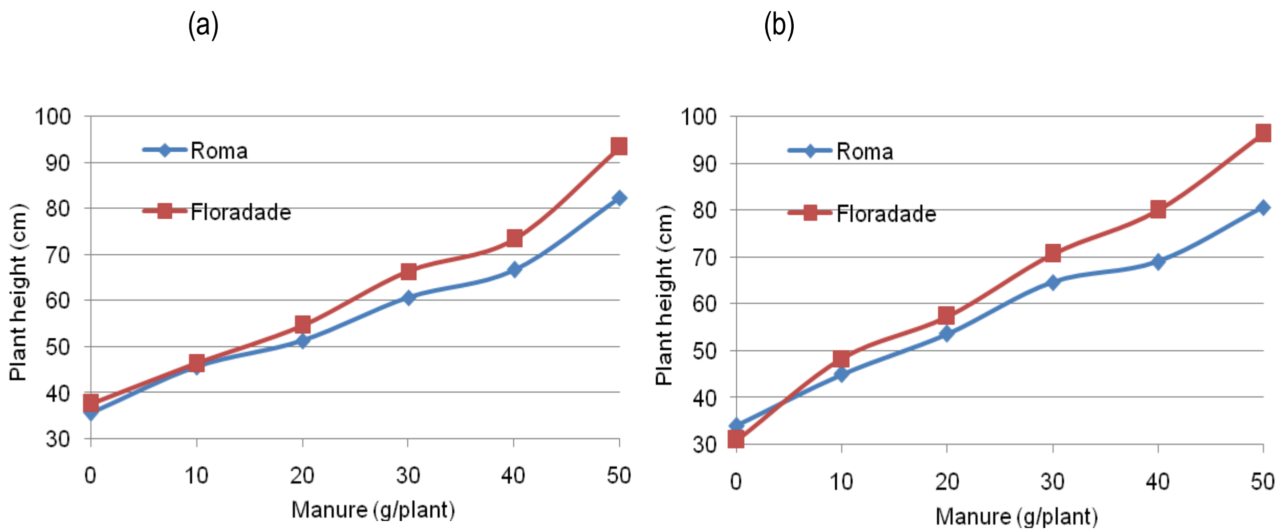

Figure 3.8 Mean responses of plant height at different levels of manure applications in two determinate tomato cultivars during Experiments I (a) and II (b)

3.3.2.2 Fruit size

There were significant differences for fruit size among cultivars and levels of manure in Experiment II (Appendix 6.14). Optimum level of manure for larger average fruit size (71 mm) was noted at 30 g per plant manure application in Experiment II (Table 3.7). The ANOVA (Appendices 6.15 and 6.16) showed that there were no significant interactions between cultivars and manure applied for fruit size. The maximum level of manure to achieve larger fruit size in both cultivars was 30 g per plant (Figure 3.9).

Table 3.7 Mean fruit size (mm) of two determinate tomato cultivars tested using six levels of manure over two experiments

Manure (g/plant)	Experiment I Cultivar			Manure (g/plant)	Experiment II Cultivar		
	Roma	Floradade	Mean		Roma	Floradade	Mean
0	50.00	57.00	53.50	0	27.33	37.67	32.50
10	61.00	60.67	60.83	10	50.00	56.33	53.17
20	65.67	62.33	64.00	20	58.67	64.67	61.67
30	71.67	65.33	64.50	30	67.00	74.67	70.83
40	63.33	66.00	64.67	40	56.67	69.33	63..00
50	62.00	67.00	68.50	50	48.67	70.67	59.67
Mean	62.28	63.28	62.67	Mean	51.39	62.22	56.81
$LSD_{0.05}$ Cultivar = 3.58 $LSD_{0.05}$ Manure = 6.22 $LSD_{0.05}$ Cultivar x Manure = 8.78					$LSD_{0.05}$ Cultivar = 5.04 $LSD_{0.05}$ Manure = 8.73 $LSD_{0.05}$ Cultivar x Manure = 12.35		

(a) (b)

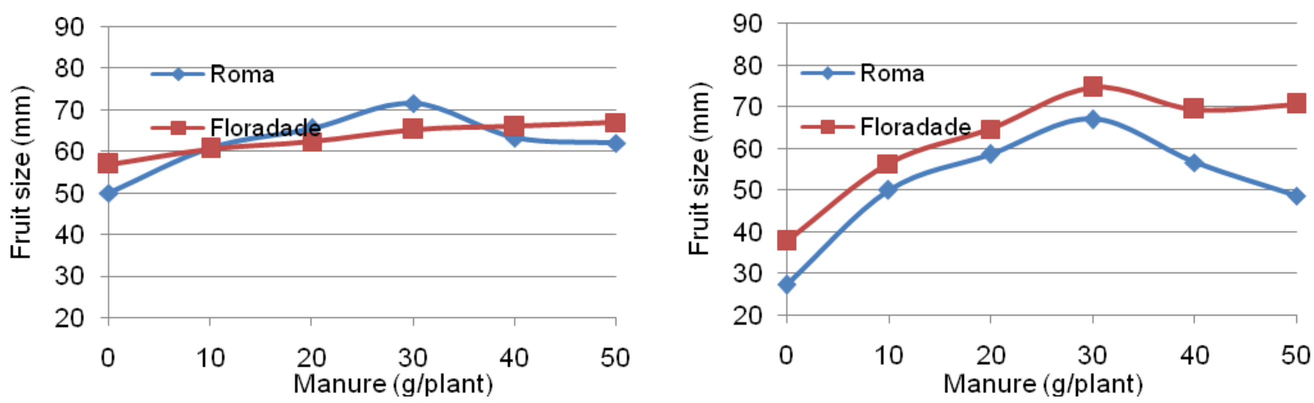

Figure 3.9 Mean responses of fruit size at different levels of manure applications in two determinate tomato cultivars during Experiments I (a) and II (b)

3.3.2.3 Fruit number

There were significant differences among cultivars and levels of manure applied on fruit number (Appendices 6.15 and 6.16). The best level of manure for maximum average fruit number at 48 and 56 was achieved at 50 g per plant in both Experiments I and II, respectively (Table 3.8). Compared to cultivar Floradade, Roma yielded the highest number of fruit of 48 and 42 during Experiment I and II, respectively (Table 3.8). There were no significant interactions detected between cultivars and manure levels for fruit number in both Experiments I and II (Appendices 6.15 and 6.16). However, highest numbers of fruit (57) were attained at 50 g of manure applied per plant in cultivar Floradade (Table 3.8). Fruit number ranged from 28 to 55 in Experiment I and 20 to 55 in Experiment II in cultivar Roma. Floradade provided 27 to 45 and 16 to 56 fruits in Experiments I and II, respectively. Figure 3.10 shows that the maximum level of manure with higher numbers of fruits were 30 g manure application in spite of differential response between the two cultivars.

Table 3.8 Mean fruit number of two determinate tomato cultivars tested using six levels of manure over two experiments

Manure (g/plant)	Experiment I Cultivar			Manure (g/plant)	Experiment II Cultivar		
	Roma	Floradade	Mean		Roma	Floradade	Mean
0	28.67	27.00	27.83	0	20.33	16.33	18.33
10	43.33	33.00	38.17	10	35.00	26.67	30.83
20	53.00	36.33	44.67	20	43.00	29.33	36.17
30	55.00	38.33	44.83	30	49.00	41.33	45.17
40	53.33	36.33	46.67	40	51.67	51.33	51.50
50	51.67	45.00	48.33	50	55.00	56.67	55.83
Mean	47.50	36.00	41.75	Mean	42.33	36.94	39.64
$LSD_{0.05}$ Cultivar = 2.74 $LSD_{0.05}$ Manure = 4.76 $LSD_{0.05}$ Cultivar x Manure = 6.73					$LSD_{0.05}$ Cultivar = 3.24 $LSD_{0.05}$ Manure = 5.60 $LSD_{0.05}$ Cultivar x Manure = 7.92		

(a) (b)

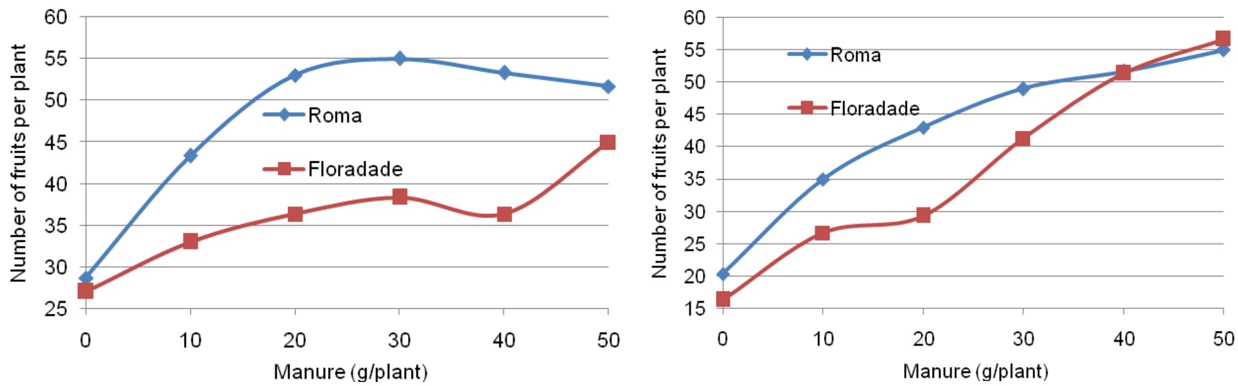

Figure 3.10 Mean responses of fruit number at different levels of manure applications in two determinate tomato cultivars during Experiments I (a) and II (b)

3.3.2.4 Total soluble solids

Significant differences were observed (Appendices 6.17 and 6.18) among cultivars and levels of manure on total soluble solid (TSS). High level of average total soluble solids (7%) was obtained at higher manure levels i.e. 40 and 50 g per plant (Table 3.9). Cultivar Roma had higher level of total soluble solids at 7 and 6% during Experiments I and II, respectively (Table 3.9). Total soluble solids ranged from 6 to 7% in Experiment I and 5 to 6% in Experiment II in cultivar Roma, whereas cultivar Floradade had 6 to 7% and 5 to 6% in Experiments I and II, respectively. Cultivar Roma had better response of TSS for manure application than Floradade. In cultivar Roma manure application of 40 g/plant and Floradade 30 g/plant would be sufficient to attain the maximum TSS (Figure 3.11).

Table 3.9 Mean total soluble solids (%) of two determinate tomato cultivars tested using six levels of manure over two experiments

Manure (g/plant)	Experiment I Cultivar			Manure (g/plant)	Experiment II Cultivar		
	Roma	Floradade	Mean		Roma	Floradade	Mean
0	6.00	6.00	6.00	0	5.33	5.00	5.17
10	5.67	6.00	5.83	10	5.67	5.00	5.33
20	6.33	6.00	6.17	20	6.00	5.67	5.83
30	6.67	6.67	6.67	30	6.00	5.67	5.83
40	7.33	6.67	7.00	40	6.00	5.67	5.83
50	7.00	7.00	7.00	50	6.00	5.67	5.83
Mean	6.50	6.39	6.44	Mean	5.83	5.56	5.69
$LSD_{0.05}$ Cultivar = 0.29 $LSD_{0.05}$ Manure = 0.38 $LSD_{0.05}$ Cultivar x Manure = 0.54					$LSD_{0.05}$ Cultivar = 0.18 $LSD_{0.05}$ Manure = 0.31 $LSD_{0.05}$ Cultivar x Manure = 0.43		

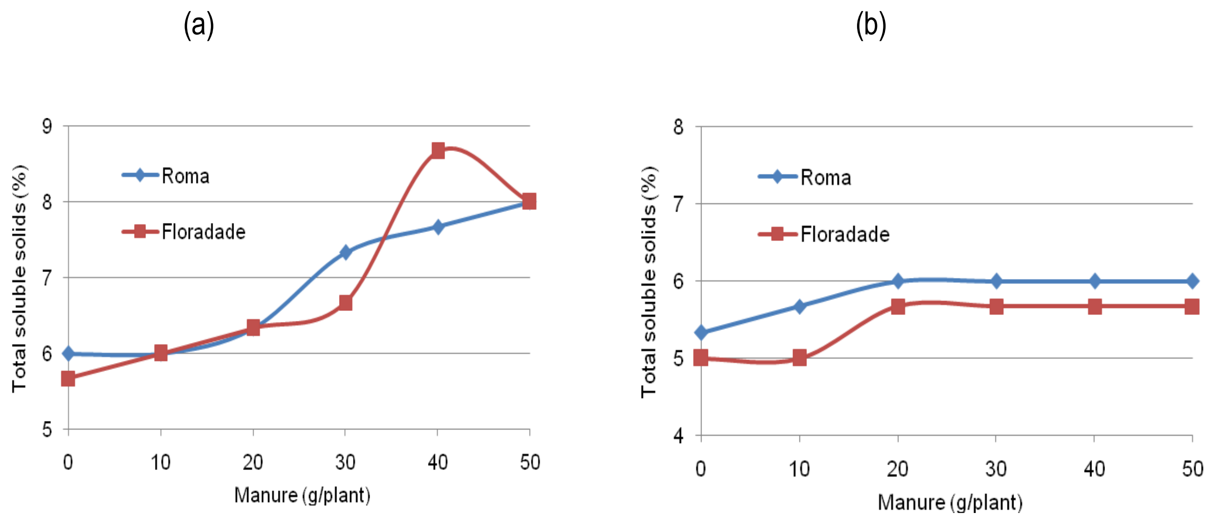

Figure 3.11 Mean responses of total soluble solids at different levels of manure applications in two determinate tomato cultivars during Experiments I (a) and II (b)

3.3.2.5 Fruit yield

In Experiment I fruit yield showed significant differences among cultivars and levels of manure applied (Appendix 6.19). Significant interactions between cultivars and levels of manure on fruit yield were evident only in Experiment II (Appendix 6. 20). Results showing average fruit yield of cultivars against six levels of manure are summarized in Table 3.10. The best level of interactions with maximum average fruit yield of 29 840 kg/ha was obtained by cultivar Roma at 30 g per plant. At 40 g per plant manure application increased fruit yield at 29 258 and 27 538 kg/ha during Experiments I and II, respectively (Table 3.10). Cultivar Roma had the highest average fruit yield (26 318 kg/ha) compared to Floradade that yielded 19 801 kg/ha. Although no statistical significant differences were found on average fruit yield in Experiment I, increased fruit yield (34 705 kg/ha) was attained by cultivar Roma at 30 g per plant manure application. The lowest average fruit yield (1 103 kg/ha) was noted when manure was totally not applied. As depicted in Figure 3.12, 30 g per plant manure application was the best level with highest average fruit yield i.e. 34 705 kg/ha in cultivar Roma. However, cultivar Floradade had better yield response at 40 g per plant in both experiments.

Table 3.10 Mean fruit yield (kg/ha) of two determinate tomato cultivars tested using six levels of manure over two experiments

	Experiment I				Experiment II		
	Cultivar				Cultivar		
Manure (g/plant)	Roma	Floradade	Mean	Manure (g/plant)	Roma	Floradade	Mean
0	11039	7928	9484	0	3169	9308	6239
10	28873	21685	25279	10	22148	21559	21854
20	30151	16347	23249	20	25454	23212	24333
30	34705	17566	26136	30	29840	25121	27481
40	31982	26533	29258	40	27395	27680	27538
50	21154	28748	24951	50	17827	29135	23481
Mean	26318	19801	23060	Mean	20972	22669	21821
$LSD_{0.05}$ Cultivar = 4774 $LSD_{0.05}$ Manure = 8269 $LSD_{0.05}$ Cultivar x Manure = 11693					$LSD_{0.05}$ Cultivar = 2089 $LSD_{0.05}$ Manure = 3619 $LSD_{0.05}$ Cultivar x Manure = 5118		

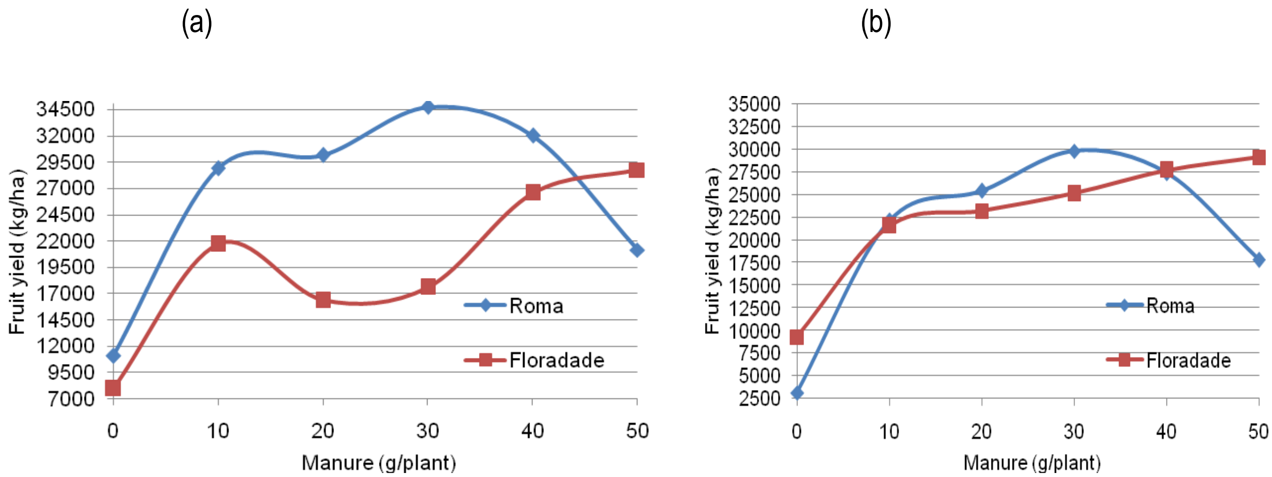

Figure 3.12 Mean responses of fruit yield at different levels of manure applications in two determinate tomato cultivars during Experiments I (a) and II (b)

3.3.3 Preliminary soil analysis

Prior to the study soil analyses showed (in mg/kg) 109 N, 55 P, 247 K, 890 Ca and 463 Mg. Overall, the soil was acidic (pH 5.5), low in total N, available P and K (Table 3.11).

After both experiments manure addition increased total N and available P and K considerably (Table 3.11). Further, the soil had increased amount of Ca and Mg than in soil before the addition of manure. The pH of the soil was slightly higher following both experiments (Table 3.11).

Table 3.11 Manure and soil chemical properties before and after the experiments

		Soil		
Composition/Property	Manure	Before experiment	After Experiment I	After Experiment II
N (mg/kg)	1980	109	1851	1838
P (mg/kg)	630	55	562	522
K (mg/kg)	1700	247	1443	1421
Ca (mg/kg)	1130	890	221	211
Mg (mg/kg)	490	463	38	45.5
pH	7.4	5.5	6.0	6.2

3.3.4. Correlation analysis of yield and yield components of indeterminate tomato cultivars during Experiments I and II

A positive and significant correlation ($P < 0.05$) was observed between plant height, fruit size, fruit number, total soluble solids and fruit yield in Experiment I (Tables 3.12). These associations were present during Experiment II (Table 3.12) except between total soluble solids and fruit yield. The association suggests that the traits are important and should be simultaneously selected when testing tomato cultivars under organic farming.

Table 3.12 Correlation analysis for pair-wise comparison of yield and yield components among three selected indeterminate tomato varieties during Experiments I and II.[a]

Experiment I				
Trait	PH	FS	FN	TSS
FS	0.68**			
FN	0.78**	0.59*		
TSS	0.78**	0.66**	0.58**	
FY	0.36*	0.64**	0.42**	0.46**
Experiment II				
	PH	FS	FN	TSS
FS	0.62**			
FN	0.60**	0.34**		
TSS	0.68**	0.16**	0.54**	
FY	0.49**	0.49**	0.52**	0.25 ns

[a] PH = Plant height; FS = Fruit size; FN = Fruit number; TSS = Total soluble solids; FY = Fruit yield

*, and ** denote significant correlations at $P < 0.05$ and $P < 0.01$, respectively; ns = non-significant difference

3.3.5 Correlation analysis on yield and yield components of determinate tomato cultivar during Experiments I and II

During Experiment I no associations were observed between fruit number with plant height and fruit size. There existed non significant but positive correlation between fruit yield and plant height (Table 3.13). All yield and yield components measured in Experiment II showed positive and significant correlation with one another (Table 3.13). This trend was similar to the response of indeterminate tomato cultivars (Table 3.12).

Table 3.13 Correlation analysis for pair-wise comparison of yield and yield components among two selected determinate tomato varieties during Experiments I and II.[a]

Experiment I				
Trait	PH	FS	FN	TSS
FS	0.52**			
FN	0.08 ns	0.04 ns		
TSS	0.64**	0.41*	0.25*	
FY	0.26 ns	0.39*	0.61**	0.38*
Experiment II				
	PH	FS	FN	TSS
FS	0.56**			
FN	0.84**	0.46**		
TSS	0.40*	0.36**	0.50**	
FY	0.54**	0.65**	0.57**	0.37*

[a] PH = Plant height; FS = Fruit size; FN = Fruit number; TSS = Total soluble solids; FY = Fruit yield

*, and ** denote significant correlations at $P < 0.05$ and $P < 0.01$, respectively; ns = non-significant difference

3.4 DISCUSSION

The present study found significant interactions among determinate and indeterminate tomato cultivars using various levels of manure applications. Manure requirement of tomato cultivars vary due to genotypic differences and fertility status of the soil (Najafvand *et al*., 2008). Manure improves the soil physical, chemical and biological properties along with conserving the moisture holding capacity and thus enhanced yield and quality of the crop (Premsekhar and Rajashree, 2009). In the present study manure level at 40 g per plant rendered increased average plant height in indeterminate cultivars in Experiment I (Table 3.1). This was attributable to improved chemical properties of the soil in terms of nitrogen. The results agreed with Najafvand *et al*. (2008) who reported increased plant at higher level of nitrogen. Reduced plant height at low levels of manure could be due to poor physical structure, chemical composition, and biological properties and reduced moisture holding capacity of the soil (Akanbi *et al*., 2003; Bhaskara Roa and Charyulu, 2005). Increased plant height noted in this study could be associated to better response of cultivars in terms of vegetative growth to manure application which is rich in nitrogen. At 40 g per plant manure application the soil pH level is fairly optimum to promote absorption of water and nutrients. Reduced plant height of cultivar Money Maker and Sweetie compared to cultivar Ox Hart was due to poor response of growth of these cultivars to the manure applied. Similar results were obtained in tomatoes by Amini and Ehsanpour (2006) who reported that reduction in vegetative growth of tomato with increasing manure was due to poor response of those cultivars to manure.

In the indeterminate cultivars the best levels of manure that provided increased average fruit size at 72 and 75 mm, respectively, during Experiments I and II was at 40 g per plant (Table 3.2). There was reduced fruit size in Experiments I and II at 50 g per plant. This could be caused by acidifying effect of manure to the soil at 50 g per plant. This suggests that pH tended to lower with a rise in the amount of manure applied. Soil acidity could cause nutrient imbalance in the crop and a reduction in the uptake of certain nutrients (Ewulo *et al*., 2008). Acidic soil permits excessive absorption of nutrients, which lead to toxic levels of this element. This response agrees with the study of Nehra *et al*. (2001) and Sanwal *et al*. (2007) who reported that the higher the rate of manure used the smaller the fruit sizes. However, cultivar Money Maker responded relatively better with average fruit sizes of 64 mm compared to Ox Hart (59 mm) and Sweetie (59 mm) in Experiment I (Table 3.2). Greater average fruit size (90 mm) was measured when 50 gram per plant was applied in cultivar Money Maker in Experiment II (Figure 3.2).

The level of manure with increased average number of fruits per plant (71 and 81 fruit) was at 40 g per plant in both Experiments I and II in the indeterminate cultivars (Table 3.3). Cultivar Ox Heart had increased average number of fruit in Experiment II (73) than cultivar Money Maker (51) and Sweetie (60). Similarly increased number of fruit (97) was observed for cultivar Ox Heart when 40 g per plant was applied (Figure 3.3). This could be due to optimum level of nitrogen content of manure applied. Manure application promotes flower and fruit set and nitrogen deficient plants results in higher rate of flower drops hence less number of fruit development (Anburani and Manivannan, 2002).

Tomato flavour is generally determined by the content of soluble solids (Barrett *et al*., 2007). Winter (2006) discussed that flavour is related to total sugar and acid. Higher brix content in tomato was evident under organic production system that resulted in reduced processing costs (Barret *et al*., 2007). In this study maximum total soluble solids (10%) was noted at 40 g per plant in Experiment II (Table 3.4). Cultivar Money Maker yielded higher total soluble solids (8%) compared to cultivar Ox Heart (7%) and Sweetie (6%). The current result is contrary to that reported by Barrett *et al.* (2007) who indicated TSS in the ranges of 4.66 to 5.39% when testing qualitative and nutritional differences in processing tomatoes. An increased total soluble solid at the present study are attributable to positive response to applied manure that improved the soil physical, chemical and biological properties as well as good moisture holding capacity of the soil.

The study reported that application of 40 g per plant of manure provided the best fruit yield of 39350 kg/ha (Table 3.5). This increase in average yield is due to improved macro and micro nutrients in the soil. Yield in tomato can be greatly increased with manure application that improves soil nutrients (Maerere *at al*., 2001; Adeniyan and Ojeniy 2003; Adediran *et al*., 2003; Akande and Adediran, 2004). However, there was reduction in yield at 50 g per plant of manure (Table 3.5) which was possibly brought about by poor physical structure and imbalance of macro and micro nutrients of the soil caused by acidic soil. Low level of soil pH could cause nutrient imbalance and a reduction in the uptake of certain nutrients and water (Ewulo *et al*., 2008). All levels considered i.e. 10, 20, 30, 40, 50 g per plant had better yield than no manure application (Table 3.5). High yields in the present study (42 052 kg/ha) was not in agreement to the report of Akande and Adediran (2004) who indicated a yield of 33 800 kg/ha. Low yield is attributed to poor soil structure caused by lower or lack of organic matter leading to reduced macro and micro nutrients. Apart from increased availability and uptake of N, P, K, Ca and Mg, manure application improves moisture retention in the soil. Improved soil moisture is associated with manure application since manure serves as mulch and improves moisture holding capacity as a result of good soil structure and porosity (Aluko and Oyedele, 2005). Consequently, overall modifications of soil properties gave rise to nutrient availability, growth and high yield in the present study. Reduced yield (22 790 kg/ha) observed at 50 g per plant in the present study may be explained by reduced nutrient availability or by low soil pH. Low soil pH should have neutralised availability of K, Ca and Mg and enhances fixation of P by Al and Fe ions (Ewulo *et al*., 2008). Soil with a low pH is a factor affecting yield of tomato across various tomato growing environments (Ewulo *et al*., 2008).

Readily available nutrients from the application of manure and water holding capacity of the soil are the prime factors for the increased plant height, fruit sizes, fruit number, total soluble solids and fruit yield of tomato (Anburani *et al*., 2003). In the determinate tomato cultivars with the exception of no application, all levels of manure made progressive increase in average plant height in the present study. However, 50 g per plant was the best among six levels of manure, with tallest average plant height of 88 cm when compared to other levels (Table 3.7). These observations are in agreement with the findings that application of organic manures increased the yield parameters of crops (Suryanarayana, 1991; Balakrishnan *et al*., 2009). In the present study cultivar Floradade had the maximum average plant height (64 cm) compared to Cultivar Roma (58) in Experiment II (Table 3.7). This is attributable to nutrient content of manure which stimulate plant growth, hence increases plant height (Parasuraman and Mani, 2003).

Maximum average fruit sizes (71 mm) of the determinate tomato were attained at 30 grams per plant of manure (Table 3.8). Larger fruit sizes (75 mm) were achieved using cultivar Floradade when manure was applied at 30 g per plant (Figure 3.8). This may be due to the accelerated mobility of photosynthates from the source to sink as influenced by the organic sources of manure (Hati *et al*., 2001).

The best level of manure for maximum average fruit number was achieved at 50 g per plant in both Experiments I and II (Table 3.9). However, there were no significant interactions between cultivars and levels of manure applied on fruit number (Appendices 6.15 and 6.16). Greater number of fruit was attained when manure was applied at 50 g per plant using cultivar Floradade (Table 3. 9). This was attributed to the supply of essential nutrients by continuous mineralisation of manures, enhanced inherent nutrient supplying capacity of the soil and its favourable effect on the physical and biological properties of the soil.

In the determinate cultivars, level of manure that rendered maximum level of average total soluble solids (7%) was at 40 and 50 g per plant (Table 3.10). The best cultivar that measured higher level of total soluble solids was cultivar Roma in both Experiments I and II. The maximum level of manure for best average total soluble solids was achieved at 40 g per plant due to combined effects of increased uptake of nutrients in plants, available nutrients, microbial population and enzymatic activities.

In the determinate cultivars, significant interactions between cultivars and levels of manure applied were detected on fruit yield in Experiment II (Appendix 6. 20). Maximum fruit yield of 29258 and 27538 kg/ha were attained at 30 g manure in both Experiments I and II (Table 3.11). Highest average fruit yield (26318 kg/ ha) was recorded for cultivar Roma than cultivar Floradade (19801 kg/ha). The best level of manure for the highest average fruit yield was achieved at 30 g per plant in cultivar Roma (Figure 3.11).

On average, untreated level (0 g per plant) rendered poor results in terms of plant height, fruit size, fruit number, total soluble solids and fruit yield. This poor performance at 0 g per plant has been attributed mainly to limited nutrients and water in the soil.

Yield is a complex entity associated with number of component characters. It is the prime concern of producers and the final factor on which selection programs are envisaged. All changes in the yield must be accompanied by changes in one or more characters. This is due to varying degrees of positive and negative correlation between yield and its components and among components themselves. Plant height was positively correlated with yield in the present study (Table 3.15). Plant height showed significant positive association with number of fruit per plant and total soluble solids in the present study. Number of fruit per plant was positively correlated with the fruit yield due to production of more number of fruit that contributed to high yield in tomatoes (Jawahaial, 1994; Sankari, 2000).

Manure addition was found to increase total N and available P and K after both experiments (Table 3.11). Ca and Mg were also increased considerably than in soil before the addition of manure. These findings are in agreement with Mafongoya *et al*. (1997) who reported that nitrogen, phosphorus and potassium are constituents of organic manures that are released through mineralisation. Sanchez *et al*. (1989) further reported that addition of organic manures to soil does not only improve soil microbial activities and physical properties but boosts chemical properties of the soil.

The pH of the soil in this study was slightly higher following both experiments (Table 3.11). This result was in agreement with Brady and Weil (1999) who reported that manure improves soil structure and pH. These workers confirmed that manure provides much of the pH buffering capacity through enhanced cation exchange capacity, acid and base functional groups.

CHAPTER 4

SUMMARY AND CONCLUSIONS

- Manure at the rate of 40 g per plant using indeterminate cultivar Sweetie contributed to higher fruit yield and increased fruit size.
- Plant height and fruit number also benefited from the same level (40 g per plant) of manure application using indeterminate cultivar Ox Heart.
- However, 30 g per plant of manure was the best level of manure for maximum fruit yield in the determinate cultivar Roma.
- Therefore, this study revealed that manure at the rate of 600 and 800 kg per hectare using determinate and indeterminate tomato cultivars provides the maximum benefit to tomato farmers in Limpopo Province or other similar environments.
- In support of the current experiment further related in-depth studies are required under field conditions including wide ranges of tomato cultivars that are adapted in Limpopo Province.
- Traits including number of clusters per plant, number of fruit per cluster, days to 50% flowering, days to 50% fruiting and number of branches per plant should be included and that would possibly explain yield potential of determinate and indeterminate tomato cultivars.

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6. APPENDICES

Appendix 6.1 Analysis of variance of plant height after testing three selected indeterminate tomato cultivars using six levels of manure under three replications during Experiment I

Source of variation	Degree of freedom	Sum of square	Mean square	F-value	Pr > F
Replication	2	47.148	23.574	0.26 ^{ns}	0.7730
Cultivar	2	1900.481	950.241	10.47**	0.0004
Residual	4	840.741	210.185		
Manure	5	25371.870	5074.374	55.90**	0.0000
Manure * Cultivar	10	1312.185	131.219	1.45 ^{ns}	0.2088
Residual	30	2723.444	90.781		
Total	53	32195.870			
Grand mean = 131.759		R^2 = 91.54%		C.V = 7.23%	

^{ns} = non significant, * significant at P < 0.05,** significant at P < 0.01

Appendix 6.2 Analysis of variance of plant height after testing three selected indeterminate tomato cultivars using six levels of manure under three replications during Experiment II

Source of variation	Degree of freedom	Sum of square	Mean square	F-value	Pr > F
Replication	2	376.704	188.352	3.53*	0.0419
Cultivar	2	6563.370	3281.685	61.55**	0.0000
Residual	4	605.185	152.296		
Manure	5	20523.037	4104.607	76.99**	0.0000
Manure * Cultivar	10	3640.185	364.019	6.83**	0.0000
Residual	30	1599.444	53.315		
Total	53	33307.926			
Grand mean = 120.963		R^2 = 95.20%		C.V = 6.04%	

^{ns} = non significant, * significant at $P < 0.05$,** significant at $P < 0.01$

Appendix 6.3 Analysis of variance of fruit size after testing three selected indeterminate tomato cultivars using six levels of manure under three replications during Experiment I

Source of variation	Degree of freedom	Sum of square	Mean square	F-value	Pr > F
Replication	2	3823.815	1911.907	81.69**	0.0000
Cultivar	2	293.370	146.685	6.27**	0.0053
Residual	4	612.741	153.185		
Manure	5	7286.759	1457.352	62.27**	0.0000
Manure * Cultivar	10	1872.630	187.263	8.00**	0.0000
Residual	30	702.111	23.404		
Total	53	14591.426			
Grand mean = 60.463		R^2 = 94.93%		C.V = 8.19%	

^{ns} = non significant, * significant at $P < 0.05$,** significant at $P < 0.01$

Appendix 6.4 Analysis of variance of fruit size after testing three selected indeterminate tomato cultivars using six levels of manure under three replications during Experiment II

Source of variation	Degree of freedom	Sum of square	Mean square	F-value	Pr > F
Replication	2	1316.037	658.019	17.50**	0.0000
Cultivar	2	1754.037	877.019	23.32**	0.0000
Residual	4	563.630	140.907		
Manure	5	14526.815	2905.363	77.25**	0.0000
Manure* Cultivar	10	1340.185	134.019	3.56**	0.0033
Residual	30	1128.333	37.611		
Total	53	206229.037			
Grand mean = 57.593		R^2 = 94.53%		C.V = 10.65%	

ns = non significant, * significant at P < 0.05,** significant at P < 0.01

Appendix 6.5 Analysis of variance of fruit number after testing three selected indeterminate tomato cultivars using six levels of manure under three replications during Experiment I

Source of variation	Degree of freedom	Sum of square	Mean square	F-value	Pr > F
Replication	2	2407.259	1203.630	9.02**	0.0009
Cultivar	2	2493.037	1246.519	9.34**	0.0007
Residual	4	1255.296	313.824		
Manure	5	10890.370	2178.074	16.33**	0.0000
Kraal manure* Cultivar	10	2047.852	204.785	1.54 ns	0.1756
Residual	30	4002.111	133.404		
Total	53	23095.926			
Grand mean = 59.037		R^2 = 82.67%		C.V = 19.56%	

ns = non significant, * significant at P < 0.05,** significant at P < 0.01

Appendix 6.6 Analysis of variance of fruit number after testing three selected indeterminate tomato cultivars using six levels of manure under three replications during Experiment II

Source of variation	Degree of freedom	Sum of square	Mean square	F-value	Pr > F
Replication	2	107.370	53.685	1.19 [ns]	0.3182
Cultivar	2	4406.037	2203.019	48.83**	0.0000
Residual	4	505.852	126.463		
Manure	5	18058.093	3611.619	80.05**	0.0000
Manure * Cultivar	10	1031.296	103.130	2.29*	0.0392
Residual	30	1353.444	45.115		
Total	53	25462.093			
Grand mean = 61.130		R^2 = 94.68%		C.V = 10.99%	

[ns] = non significant, * significant at $P < 0.05$,** significant at $P < 0.01$

Appendix 6.7 Analysis of variance of total soluble solid after testing three selected indeterminate tomato cultivars using six levels of manure under three replications during Experiment I

Source of variation	Degree of freedom	Sum of square	Mean square	F-value	Pr > F
Replication	2	13.370	6.685	6.00**	0.0064
Cultivar	2	1.815	0.907	0.81 ns	0.4526
Residual	4	7.185	1.796		
Manure	5	33.426	6.685	6.00**	0.0006
Manure* Cultivar	10	4.670	0.463	0.42 ns	0.9282
Residual	30	33.444	1.115		
Total	53	93.870			
Grand mean = 6.759		R^2 = 64.37%		C.V = 15.62%	

ns = non significant, * significant at $P < 0.05$,** significant at $P < 0.01$

Appendix 6.8 Analysis of variance of total soluble solid after testing three selected indeterminate tomato cultivars using six levels of manure under three replications during Experiment II

Source of variation	Degree of freedom	Sum of square	Mean square	F-value	Pr > F
Replication	2	12.037	6.019	5.09 *	0.0125
Cultivar	2	13.593	6.796	5.75**	0.0077
Residual	4	25.185	6.296		
Manure	5	135.648	27.130	22.96**	0.0000
Manure* Cultivar	10	11.074	1.107	0.94^{ns}	0.5144
Residual	30	35.444	1.181		
Total	53	232.981			
Grand mean = 6.981		R^2 = 84.79%		C.V = 15.57%	

^{ns} = non significant, * significant at P < 0.05,** significant at P < 0.01

Appendix 6.9 Analysis of variance of fruit yield after testing three selected indeterminate tomato cultivars using six levels of manure under three replications during Experiment I

Source of variation	Degree of freedom	Sum of square	Mean square	F-value	Pr > F
Replication	2	145329017.5	72664508.7	2.32 ^{ns}	0.1153
Cultivar	2	555450651.7	277725325.9	8.88 **	0.0009
Residual	4	193115941.6	48278985.4		
Manure	5	5203720300.8	1040744060.2	33.28**	0.0000
Manure * Cultivar	10	1543774556.3	154377455.6	4.94**	0.0003
Residual	30	938292371.556	31276412.385		
Total	53	8579682839.5			
Grand mean = 26730.481		R^2 = 89.06%		C.V = 20.92%	

^{ns} = non significant, * significant at $P < 0.05$,** significant at $P < 0.01$

Appendix 6. 10 Analysis of variance of fruit yield after testing three selected indeterminate tomato cultivars using six levels of manure under three replications during Experiment II

Source of variation	Degree of freedom	Sum of square	Mean square	F-value	Pr > F
Replication	2	7693305.5	3846652.7	0.21 [ns]	0.8130
Cultivar	2	919933943.3	459966971.6	24.93 **	0.0000
Residual	4	55217811.0	13804452.7		
Manure	5	4595874319.5	919174863.9	49.81**	0.0000
Manure * Cultivar	10	1671472564.3	1671147256.4	9.06 **	0.0000
Residual	30	553577142.222	18452571.407		
Total	53	7803769085.7			
Grand mean = 27797.074		R^2 = 92.91%		C.V = 15.45%	

[ns] = non significant, * significant at $P < 0.05$,** significant at $P < 0.01$

Appendix 6.11 Analysis of variance of plant height after testing two selected determinate tomato cultivars using six levels of manure under three replications during Experiment I

Source of variation	Degree of freedom	Sum of square	Mean square	F-value	Pr > F
Replication	2	360.500	180.250	9.76**	0.0011
Cultivar	1	215.111	215.111	11.65**	0.0028
Residual	2	768.056	384.028		
Manure	5	10049.333	2009.867	108.80**	0.0000
Manure* Cultivar	5	104.556	20.911	1.13 ^{ns}	0.3758
Residual	20	369.444	18.472		
Total	35	11867.000			
Grand mean = 59.500		R^2 = 96.89%		C.V = 7.22%	

^{ns} = non significant, * significant at P < 0.05,** significant at P < 0.01

Appendix 6.12 Analysis of variance of plant height after testing two selected determinate tomato cultivars using six levels of manure under three replications during Experiment II

Source of variation	Degree of freedom	Sum of square	Mean square	F-value	Pr > F
Replication	2	171.556	85.778	2.04 ns	0.1564
Cultivar	1	336.111	336.111	7.99*	0.0104
Residual	2	374.222	187.111		
Manure	5	12184.889	2436.978	57.96**	0.0000
Manure* Cultivar	5	317.889	63.578	1.51 ns	0.2306
Residual	20	840.889	42.044		
Total	35	14225.556			
Grand mean = 60.889		R^2 = 94.09%		C.V = 10.65%	

ns = non significant, * significant at $P < 0.05$,** significant at $P < 0.01$

Appendix 6. 13 Analysis of variance of fruit size after testing two selected determinate tomato cultivars using six levels of manure under three replications during Experiment I

Source of variation	Degree of freedom	Sum of square	Mean square	F-value	Pr > F
Replication	2	20.667	10.333	0.27 ^{ns}	0.7697
Cultivar	1	5.444	5.444	0.14 ^{ns}	0.7125
Residual	2	220.222	110.111		
Manure	5	783.333	156.667	4.02*	0.0109
Manure* Cultivar	5	193.222	38.6444	0.99 ^{ns}	0.4474
Residual	20	779.111	38.956		
Total	35	2002.000			
Grand mean = 62.667		R^2 = 61.08%		C.V = 9.96%	

^{ns} = non significant, * significant at $P < 0.05$,** significant at $P < 0.01$

Appendix 6.14 Analysis of variance of fruit size after testing two selected determinate tomato cultivars using six levels of manure under three replications during Experiment II

Source of variation	Degree of freedom	Sum of square	Mean square	F-value	Pr > F
Replication	2	426.389	213.194	2.77 ^{ns}	0.0866
Cultivar	1	1056.250	1056.250	13.73**	0.0014
Residual	2	978.267	489.083		
Manure	5	5225.806	1045.161	13.59**	0.0000
Manure* Cultivar	5	272.917	54.583	0.71 ^{ns}	0.6231
Residual	20	1538.111	76.906		
Total	35	9497.639			
Grand mean = 56.806		R^2 = 83.81%		C.V = 15.44%	

^{ns} = non significant, * significant at P < 0.05,** significant at P < 0.01

Appendix 6.15 Analysis of variance of fruit number after testing two selected determinate tomato cultivars using six levels of manure under three replications during Experiment I

Source of variation	Degree of freedom	Sum of square	Mean square	F-value	Pr > F
Replication	2	3510.167	1755.083	76.75**	0.0000
Cultivar	1	1190.250	1190.250	52.05**	0.0000
Residual	2	1301.167	650.583		
Manure	5	1752.250	350.450	15.33**	0.0000
Manure* Cultivar	5	307.583	61.517	2.69 ^{ns}	0.0513
Residual	20	457.333	22.857		
Total	35	8518.750			
Grand mean = 41.750		R^2 = 94.63%		C.V = 11.45	

^{ns} = non significant, * significant at $P < 0.05$,** significant at $P < 0.01$

Appendix 6.16 Analysis of variance of fruit number after testing two selected determinate tomato cultivars using six levels of manure under three replications during Experiment II

Source of variation	Degree of freedom	Sum of square	Mean square	F-value	Pr > F
Replication	2	197.056	98.528	3.11 ^{ns}	0.0667
Cultivar	1	261.361	261.361	8.25**	0.0094
Residual	2	246.722	123.361		
Manure	5	5862.139	1172.428	37.01**	0.0000
Manure* Cultivar	5	239.472	47.894	1.51 ^{ns}	0.2307
Residual	20	633.556	31.678		
Total	35	7440.306			
Grand mean = 39.639		R^2 = 91.48%		C.V = 14.20%	

^{ns} = non significant, * significant at $P < 0.05$,** significant at $P < 0.01$

Appendix 6.17 Analysis of variance of total soluble solid after testing two selected determinate tomato cultivars using six levels of manure under three replications during Experiment I

Source of variation	Degree of freedom	Sum of square	Mean square	F-value	Pr > F
Replication	2	0.722	0.361	2.50 ns	0.1074
Cultivar	1	0.111	0.111	0.77 ns	0.3909
Residual	2	0.389	0.194		
Manure	5	7.889	0.578	10.92 **	0.0000
Manure* Cultivar	5	0.889	0.178	1.23 ns	0.3315
Residual	20	2.889	0.144		
Total	35	12.889			
Grand mean = 6.444		R^2 = 77.59%		C.V = 5.90%	

ns = non significant, * significant at P < 0.05,** significant at P < 0.01

Appendix 6.18 Analysis of variance of total soluble solid after testing two selected determinate tomato cultivars using six levels of manure under three replications during Experiment II

Source of variation	Degree of freedom	Sum of square	Mean square	F-value	Pr > F
Replication	2	1.056	0.528	5.59 *	0.0118
Cultivar	1	1.361	1.361	14.41**	0.0011
Residual	2	1.056	0.528		
Manure	5	2.806	0.526	5.94**	0.0016
Manure* Cultivar	5	0.139	0.028	0.29^{ns}	0.9105
Residual	20	1.889	0.094		
Total	35	8.306			
Grand mean = 5.639		R^2 = 77.26%		C.V = 5.45%	

^{ns} = non significant, * significant at $P < 0.05$,** significant at $P < 0.01$

Appendix 6. 19 Analysis of variance of fruit yield after testing two selected determinate tomato cultivars using six levels of manure under three replications during Experiment I

Source of variation	Degree of freedom	Sum of square	Mean square	F-value	Pr > F
Replication	2	135318523.6	67659261.8	0.98 ns	0.3922
Cultivar	1	382163401.0	382163401.0	5.54*	0.0289
Residual	2	289226408.0	144613204.0		
Manure	5	1444326803.2	288865360.6	4.19**	0.0091
Manure* Cultivar	5	567343647.7	113468729.5	1.65 ns	0.1939
Residual	20	1379020855	68951042.756		
Total	35	4197399638.6			
Grand mean = 23059.611		R^2 = 67.15%		C.V = 36.01%	

ns = non significant, * significant at $P < 0.05$,** significant at $P < 0.01$

Appendix 6. 20 Analysis of variance of fruit yield after testing two selected determinate tomato cultivars using six levels of manure under three replications during Experiment II

Source of variation	Degree of freedom	Sum of square	Mean square	F-value	Pr > F
Replication	2	143122824.1	71561412.0	5.42*	0.0132
Cultivar	1	25916584.0	25916584.0	1.96 ns	0.1766
Residual	2	26632985.4	13316492.7		
Manure	5	1899555103.5	379911020.7	28.76**	0.0000
Manure*Cultivar	5	263995057.5	52799011.5	4.00*	0.0112
Residual	20	264151328.556	13207566.428		
Total	35	2623373883.0			
Grand mean = 120.111		R^2 = 91.70%		C.V = 8.51%	

ns = non significant, * significant at $P < 0.05$,** significant at $P < 0.01$