# RESPONSE OF TOMATO (*Lycopersicon esculentum* Mill) TO INTEGRATED APPLICATION OF EFFECTIVE MICROORGANISMS TREATED COMPOST, CONVENTIONAL COMPOST AND INORGANIC FERTILIZERS

**M.Sc. Thesis**

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**Jimma, Ethiopia**

# RESPONSE OF TOMATO (*Lycopersicon esculentum* Mill*)* TO INTEGRATED APPLICATION OF EFFECTIVE MICROORGANISMS TREATED COMPOST, CONVENTIONAL COMPOST AND INORGANIC FERTILIZERS

**M.Sc. Thesis**

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By

**Serkalem Getahun**

**March, 2012**
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**APPROVAL SHEET**

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As Thesis Research advisors, we here by certify that we have read and evaluated this thesis prepared, under our guidance, by **Serkalem Getahun**, entitled "**Response of Tomato (*Lycopersicon esculentum* Mill*)* to Integrated Application of Effective Microorganisms Treated Compost, Conventional Compost and Inorganic Fertilizers**" we recommend that it can be submitted as fulfilling the thesis requirement.

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As member of the Board of Examiners of the M.Sc Thesis Open Defense Examination, We certify that we have read and evaluated the thesis prepared by Serkalem Getahun, and examined the candidate. We recommended that the thesis be accepted as fulfilling the thesis requirement for the Degree of Master of Science in Horticulture (Vegetable Science).

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## DEDICATION

I dedicate this thesis manuscript to all **my family** members.

## STATEMENT OF AUTHOR

First, I declare that this thesis is my own work and that all sources of material used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements of M.Sc. degree at Jimma University, College of Agriculture and Veterinary Medicine and is deposited at the University Library to be made available to users under rules of the Library. I seriously declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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# LIST OF ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| AGRISNET | Agriculture Information System Network |
| APNAN | Asia-Pacific Natural Agriculture Network |
| BCFU | Bacteria colony forming unit |
| CC | Conventional compost |
| CEC | Cation Exchange Capacity |
| CFU | Colony Forming Unit |
| CV | Coefficient of variance |
| EARO | Ethiopia Agriculture Research Organization |
| EM | Effective microorganisms |
| EMRO | Effective Microorganisms Research Organization |
| EMTC | Effective microorganism treated compost |
| ERIC | Environmental Research and Information Consortium |
| FAO | Food and Agriculture Organization of United Nations |
| FCFU | Fungi colony forming unit |
| IF | Inorganic fertilizer |
| K | Potassium |
| LSD | Least significant difference |
| N | Nitrogen |
| P | Phosphorus |
| TA | Titratable acidity |
| TSS | Total soluble solid |

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## ABSTRACT

*Tomato is the third largest vegetable crop after potato and sweet potato and as a processing crop it ranks first among all vegetables. China is the biggest tomato producer in the world, Ethiopia produces 40,426 tons every year. However, the total production and productivity in Ethiopia is far below than the average of major producers in Africa. Among many contributing factors, lack of optimum fertilizer use among tomato growers is a felt problem. In view of this fact, a 2X10 factorial experiment arranged in Randomized Complete Block Design with three replications was conducted to determine the comparative benefits of using organic and inorganic fertilizers in combination or alone on tomato (Lycopersicon esculentum Mill) production and quality in the horticultural farm of Jimma University College of Agriculture and Veterinary Medicine (JUCAVM), Jimma during 2010/2011under irrigation. The experiment consisted of two commonly grown tomato varieties Fetane and Bishola and 10 fertilizer combinations (Control (with no fertilizer), inorganic fertilizer alone, conventional compost alone, Effective microorganisms treated compost alone, ¼ Effective microorganisms treated compost + ¾ inorganic fertilizer, ½ Effective microorganisms treated compost + ½ inorganic fertilizer, ¾ Effective microorganisms treated compost + ¼ inorganic fertilizer, ¼ conventional compost + ¾ inorganic fertilizer, ½ conventional compost + ½ inorganic fertilizer and ¾ conventional compost + ¼ inorganic fertilizer). The plot size used was 2.8 m x 2.1 m. Coffee pulp was used for preparation of compost material treated with & without effective microorganisms and the inorganic fertilizers used was Urea and DAP (200kg/ha for Urea and 150kg/ha for DAP). The result revealed that the interaction of fertilizer with variety significantly ($p<0.001$) affected fruit number plant$^{-1}$, average fruit weight (g) plant$^{-1}$, total fruit yield (g) plant$^{-1}$, total fruit yield (t) hectare$^{-1}$ and marketable fruit yield (t) hectare$^{-1}$. Regarding the quality parameters Bishola performed best over Fetane. The maximum total fruit yield ha$^{-1}$ (47.92 and 37.38 t) was recorded from Fetane that received ¼ Effective microorganisms treated compost + ¾ inorganic fertilizer and full dose of inorganic fertilizer respectively. While the least (13.92 t) was recorded from the control treatment of Bishola. The same was true for marketable yield ha$^{-1}$. The maximum unmarketable fruit yield ha$^{-1}$ (4.527t) was recorded from Bishola variety. Fetane variety that received ¼ Effective microorganisms treated compost + ¾ inorganic fertilizer performed best almost for all yield contributing characteristics. It can be suggested that for obtaining higher yield of tomato fruits, which may help to reduce the use of inorganic fertilizers. Soil parameters such as organic carbon, cation exchange capacity, organic matter, bacteria and fungi colony were also significantly influenced by different proportion of fertilizers. The highest organic carbon (3.083%), CEC (19.99), organic matter (3.083%), bacteria (8.137 CFU g$^{-1}$ soil (log 10)) and fungi (6.739 CFU g$^{-1}$ soil (log 10)) colony were recorded from full dose of Effective microorganisms treated compost. It can be stated that application of organic compost specially treated by EM can significantly increase the soil nutrient content. However, before making any final recommendation the effect of these treatments should be seen on subsequent crops on that particular field and Cost benefit analysis should be done.*


***Keywords: Tomato, EM, compost, fertilizer, yield, quality***

# 1 INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) belongs to the *Solanaceae* family and it is originated in the South American Andes however, cultivated tomato originated in Mexico (Maria and Fernando, 2008). This family also includes other well-known species, such as potato, tobacco, peppers and eggplant. The cultivated tomato was brought to Europe by the Spanish conquistadors in the sixteenth century and later introduced from Europe to southern and eastern Asia, Africa and the Middle East (Shankara *et al.,* 2005). There is no definite time recorded regarding the introduction of cultivated tomato to Ethiopia. However, cherry type has been growing for long time around big cities and in small gardens (Lemma, 2002). Currently, it is the world's third largest vegetable crop after potato and sweet potato (AGRISNET, 2010).

As a processing crop, it ranks first among all vegetables grown throughout the world. Tomato is one of the most widely eaten vegetable in the world. Their popularity stems from the fact that they can be eaten fresh or in a multiple of processed forms. Three major processed products are: (i) tomato preserves (e.g. whole peeled tomatoes); (ii) dried tomatoes (tomato powder, tomato flakes, dried tomato fruits); and (iii) tomato-based foods (e.g. tomato soup, tomato sauces, chilli sauce, ketchup) (Costa and Heuvelink, 2004). It also possesses valuable medicinal properties, an excellent purifier of blood and a rich source of vitamins like vitamin A and C, flavonoid anti-oxidants than any other vegetables (Taylor, 1987).

Tomato is one of the vegetables with the highest production both in the world and at country level. Asia is by far the continent with the greatest production, China is the main producer of tomato with the area coverage of 920,803 ha and production of 45,365,543 t with productivity of 49.27 t/ha, followed by the US, Turkey, India and Italy. From Africa Egypt and Nigeria are the main tomato producers (FAOSTAT, 2011). However, the total production and productivity in Ethiopia is far below than the average of major producers in Africa. According to FAOSTAT (2011) in 2009 cropping season the country's area coverage by this crop was 4,593 ha and production in tons was 40,426 t with the productivity of 8.8 t/ha, which is very low when compared to the other tomato producer countries.

Increasing production of the crop has a great role to strengthen the growing tomato processing industries in the country. However, the production and productivity of the crop in the country is influenced by different factors. Improper or inadequate application of fertilizer and absence or lack of readily available nutrient in the soil is one of them that leads to low productivity of the crop (Teshome, 2010).

Production in agricultural systems depends largely on the action of the soil microbial biomass. Addition of organic materials (OM) to soil is an agricultural practice for enhancing soil quality. Addition of organic materials into soils also encourages plant development and suppresses occurrence of soil-borne diseases (Ncube, 2008).

For optimum plant growth, nutrients must be available in sufficient and balanced quantities. Soils contain natural reserves of plant nutrients, but these reserves are largely in forms unavailable to plants, and only a minor portion is released each year through biological activity or chemical processes. This release is too slow to compensate for the removal of nutrients by agricultural production and to meet crop requirements. Therefore, fertilizers are designed to supplement the nutrients already present in the soil (Jen, 2007).

Composting is one method of hastening release of nutrients from organic material. During the process, much of the organic nutrients are converted into inorganic forms. This makes compost more efficient than the original organic materials in supplying nutrients to crops. Alternatively, inorganic fertilizer provides readily available nutrients to crops including tomato. However, this may be accompanied by excessive absorption of nitrate and sulphate that may cause health problems in humans (Noble and Coventry, 2005). The complementary use of synthetic and organic sources of plant nutrients may provide benefits to yields and human health (Taiwo *et al.,* 2007).

Another way of supplying nutrients to soil is through biological inoculums but it also needs large amount of organic matter and alone cannot favor the plant nutrient supply to soil eco-system (Hussain *et al.*, 1999). So, one of the best alternative of nutrient supply is the integration of Effective Microorganisms (EM) and organic/inorganic materials (Shamshad *et al.,* 2001).

This type of compost comprises of organic waste broken down through fermentation. It has higher nutrient level. It contains essential nutrients, NPK and other beneficial substances such as vitamins, organic acid, minerals and antioxidants, which create favorable environment for beneficial insect and plants to grow healthy. It can make use of the inorganic fertilizer more effective and reduce losses (WAI, 2009). Effective microorganisms (EM) technology was developed in the 1980s, by a Japanese Professor Dr Teruo Higa in Japan (Higa, 1996). Different brands of EM are currently being used in over 140 countries around the world (Chamberlain and Daly, 2001). In Africa, there are seven distributor and seven EM producer (including Ethiopia) countries (EMRO, 2011). Microorganisms are important attributes in agriculture to promote the circulation of plant nutrients and reduce the need for inorganic fertilizers (Chrispaul *et al.*, 2010).

EM technology increases yield and enhances quality through improving soil fertility (application of compost), resistance to disease and pests and other environmental stresses. Therefore, the farmer may choose to use a combination of the two until the soil fertility has increased. In Ethiopia, efficacy trials were conducted at Hollota (HARC), Jimma (JARC) and Debre-Zeit (DARC) Research Centers with positive results. Consequently, Woljeejii Agricultural Industry Plc has entered into agreement with Effective Microorganism Research Organization (EMRO) in Japan, the parent organization of EM Technology. Accordingly, Woljeejii started to produce stock EM in Ethiopia since February 2009 (WAI, 2009). The use of EM is, however, not yet widespread in Ethiopia. There is some information mainly by Woljeejii Agro-Industry Plc. There is, however, only limited scientific information on the effectiveness and use of EM in Ethiopia.

In order to improve the yield and quality of tomato, there is to have the technologies, which will eventually fulfill the grower as well as consumer’s need. Studies on management practices, particularly on the management of fertilizer specially treating compost by effective microorganism would help in increasing yield of tomato. Keeping this fact in view, it is imperative to conduct the present experiment with the following objectives.

## Objectives

### General Objective

To determine the comparative benefits of using organic and inorganic fertilizers in combination or alone in respect of yield and quality of tomato

### Specific Objectives

- To evaluate effects of co-application of EM treated and untreated compost with inorganic fertilizer on growth, yield, and quality of tomatoes

- To assess the impact of integrated application of EM treated and untreated compost with inorganic fertilizers on soil characteristics

# 2 LITERATURE REVIEW

## 2.1 The Tomato Crop

### 2.1.1 Origin, botany and ecology of tomato crop

Tomato (*Lycospersicon esculentum* Mill) is a member of the *solanaceae* family and was first domesticated in the Central America as early as 700 B.C. It is diploid and has a chromosome number of 2n=24 (Maria and Fernando, 2008). It grows as a series of branching stems, with a terminal bud at the tip that does the actual growing. When that tip eventually stops growing, whether because of pruning or flowering, lateral buds take over and grow into other fully functional vines.

The leaves are 10–25 centimeters long, odd pinnate, with 5–9 leaflets on petioles, each leaflet up to 8 centimeters long, with a serrated margin; both the stem and leaves are densely glandular-hairy (David, 2010).

Tomatoes can be grown both in temperate and tropical zones. Its fruit is fleshy berry, globular to oblate in shape. The immature fruit is green and hairy. Ripe fruits range from yellow, orange to red. It is usually round, smooth or furrowed. Tomato fruits mature in about 25-30 days after fertilization (Shankara *et al.*, 2005).

MoARD (2009) reported that in Ethiopia, tomato is produced in altitudes between 700 and 2000, which is characterized as warm and dry day and cooler night and favorable for optimum growth and development of tomatoes. A temperature range between 21 to $27^0$C day and 10 to $20^0$C night is favorable for plant development, and fruit set in the country. It grows better at a constant day and night temperature. A difference of $6^0$C between day and night temperatures was found sufficient for good plant growth and development. Fruit setting is poor when the temperature is either high or low. Extreme temperatures cause flower drops and poor fruit set.

### 2.1.2 Importance of tomato

Cultivation of tomatoes improves diet of the people, as they are a part of every salad in combination with leaf vegetables, green onions, cucumbers, peppers, and other vegetables (AVRDC, 2005). As a processing crop, it ranks first among all vegetables grown throughout the world (Nileema, 2011).

Nutritional quality of tomato is mainly determined by its lycopene and vitamin C, A and E contents. Between 90-95% of the carotenoids present in ripened tomatoes are carotenes. Lycopene is the most abundant carotene in the red tomato fruit, accounting for up to 90% of the total (Maria and Fernando, 2008). A raw tomato has about 20% of the lycopene content found in cooked tomatoes. However, raw or cooked tomatoes are considered the best source for this antioxidant. Lycopene is a very powerful antioxidant, which can help prevent the development of many forms of cancer (Wener, 2000).

Consumption of natural vegetables and fruits rich in flavonoids is known to help protect from lung and oral cavity cancers. Fresh tomato is very rich in potassium. Potassium is an important component of cell and body fluids that helps controlling heart rate and blood pressure caused by sodium (Anonymous, 2011).

It is an important cash-generating vegetable crop to small-scale growers and provides opportunities for employment in the production and processing plants (Lemma *et al.*, 2003). Its production is more attractive than any other vegetable crops for its multiple harvests, which results in high profit per unit area of land (Adugna, 2009).

## 2.2 Microbes in Agriculture

Microbes are a vital component in all ecosystems. In agriculture, their value cannot be overemphasized, due to their role in the soil and as an inter link between the biotic and abiotic components, between the grazing and detritus food chains. However, their role has often been neglected in conventional chemical farming systems (Zarb *et al.*, 2001).

The activities of soil organisms are indispensable for high soil fertility and good crop production. Most of their activities are beneficial for the farmer, since they decompose organic matter to give humus, aggregate soil particles to give a better structure, protect roots from diseases and parasites, retain nitrogen and other nutrients, produce hormones that help plants grow and can convert pollutants that find their way into the soil (FAO, 2000).

The interaction between microbes and plants developed with the process of evolution in plants, and hence the use of microbes singly or in mixtures of free living and naturally occurring species could enhance the productivity of most farming systems significantly. Thus, the most important and often-used species of microbes in agriculture are Fungi, Bacteria, Actinomyces and Yeasts (Zarb *et al.*, 2001). In the recent times, research has clearly shown the benefits of using inoculations of naturally occurring microbes in increasing productivity of both conventional and organic farming systems (Tisdal, 1994).

### 2.3 Effective Micro-organisms (EM)

EM is a complex combination of microorganisms that can be found in nature and the food processing industry. This technology was developed in the 1980s, by a Japanese Professor Dr Teruo Higa. These microbes have been cultured in a special combination and developed as a technology for improving soils and plant growing conditions (Chamberlain and Daly, 2001). In 20 years EM technology has developed into a global technology, and is recognized as a powerful and effective tool both in agriculture and in horticulture for crop and animal production systems (Chamberlain and Daly, 2001).

EM is not a substitute for other management practices. It is, however, an added dimension for optimizing our best soil and crop management practices such as crop rotations, use of organic amendments, conservation tillage, crop residue recycling, and biocontrol of pests. If used properly, EM can significantly enhance the beneficial effects of these practices (Higa and Wididana, 1991).

Most of the species in EM inoculants are heterotrophic and require organic sources of carbon and nitrogen for their nutrition. Therefore, EM inoculation has been more effective when applied in combination with organic materials to provide both carbon and nitrogen (Yamada and Xu, 2000). The microorganisms contained in the concoctions reportedly produce plant hormones, beneficial bioactive substances and antioxidants while solubilizing nutrients (Higa and Parr, 1994).

EM Technology spread from Japan initially to Asia and then to Europe, North America and South America towards the end of the $20^{th}$ century. In the last decade, it has been introduced to Africa. South Africa has pioneered in producing stock EM since 1996 and is using it intensively. Likewise, Kenya, Egypt, Sudan and Ghana are also producing EM for their own use and for export. With the realization of the fact that the Ethiopian economy is based on agriculture, and considering the major production bottleneck such as poor soil fertility, erratic nature of rainfall, high incidence of diseases and pests and the growing shortage of livestock feed, EM is recommended to be effective to merit both the public and the private sector (WAI, 2009).

According to Higa and Parr (1994) the inoculation of EM cultures to the soil/plant ecosystem can improve soil quality, soil health, and the growth, yield, and quality of crops. The application of EM results in an increase in soil organisms which are beneficial for plant growth, resulting in more rapid mineralization of organic matter, suppression of soil-borne pathogens and increased crop yield and quality (APNAN, 1995). Other studies have shown that inoculation of the agro-ecosystem with EM leads to an improvement in soil and crop quality in addition to higher crop yields (Higa and Parr, 1994; Li and Ni, 1995). Daly (2004) also reported that the addition of EM to the composting process produced much higher quality compost over the 'non EM' compost.

### 2.3.1 The principal microorganisms in EM and their action in the soil

EM contains selected species of microorganisms including predominant populations of lactic acid bacteria and yeasts and smaller numbers of photosynthetic bacteria, actinomycetes and other types of organisms. All of these are mutually compatible with one another and can coexist in liquid culture Higa and Parr (1994). These microorganisms are completely natural and all are found in the environment, with many found also in food processing applications, e.g. Lactic acid bacteria in Yoghurt (Daly and Stewart, 1999).

Effective Microorganisms (EM) are a mixed culture of fermentative, soil-based, beneficial microorganisms that can be applied to many environments to improve the health and vitality of water, soil, plants and animals (Robert, 2009).

The first solutions contained over 80 species from 10 genera. With time, the technology was refined to include only the four important species, namely Lactic Acid Bacteria, Photosynthetic Bacteria, Actinomyces and Yeast (Robert, 2009). It has been scientifically documented that these organisms in mixed cultures, and through fermentation reactions, produce organic acids, plant hormones (e.g., auxins, gibberellins, and cytokinins), vitamins, and anti-biotics (Higa, 1996).

The key to the success of EM is not the microbes working in isolation from each other but the combination and synergistic effect when they are used together. This is what makes EM so effective. The diverse combination of microbes in EM also gives it adaptability and this is why it works in such a broad range of conditions (Daly and Stewart, 1999).

Phototrophic bacteria (also known as photosynthetic bacteria) are an ancient type of bacteria in existence from before the Earth had its present concentration of oxygen. As its name indicates, these bacteria utilize solar energy to metabolize organic and inorganic substances. Phototrophic bacteria are involved in various metabolic systems, and play a major role in nitrogen cycling and carbon cycling. Because this role allows the other microorganisms in EM to co-exist, phototrophic bacteria are the essential elements of EM (EMRO, 2011). These bacteria synthesize useful substances from secretions of roots, organic matter and/or harmful gases (e.g. hydrogen sulfide). Useful substances developed by these microbes include amino acids, nucleic acids, bioactive substances and sugars, all of which promote plant growth and development. The metabolites (the breakdown and build-up of compounds in metabolism, e.g. enzymes, growth regulators, hormones, etc.) developed by these microorganisms are absorbed directly into plants and act as substrates for increasing beneficial populations (Robert, 2009).

Lactic acid bacteria is, taxonomically, a generic term for bacteria that convert large amounts of sugars into lactic acid through lactic acid fermentation. Through the production of lactic acid, lactic acid bacteria also inhibit the growth of pathogenic microorganisms and other various microorganisms by lowering the pH (EMRO, 2011). Lactic acid bacteria promote the decomposition of material such as lignin and cellulose and ferment these materials, thereby removing undesirable effects of un-decomposed organic matter (Robert, 2009).

Yeast (known as a fermentation starter) is a microorganism necessary for the brewing of alcohol and the making of bread (EMRO, 2011). Yeasts synthesize anti-microbial and other useful substances required for plant growth from amino acids and sugars secreted by photosynthetic bacteria, organic matter and plant roots. The bioactive substances such as hormones and enzymes produced by yeasts promote active cell and root division. These secretions are also useful substrates for effective microbes such as lactic acid bacteria and actinomycetes. EM also comprises fermentative fungi and actinomycetes (Robert, 2009).

### 2.3.2 Application of Effective Microorganisms

EM has its application in agriculture via a number of methods. As seed treatment to accelerate germination and to protect the seeds and seedlings from harmful pathogens, in composting of farm wastes to prepare enriched compost, as foliar spray to improve growth, yield and quality of crops by way of enhancing the photosynthetic efficiency and protecting crops from pests and diseases, soil application through irrigation water (Sundaram *et al.,* 2004).

The virtue of EM technology is production of quality compost with in a comparatively short span of time and enhancement of nutrient release that would have otherwise remained locked in the soil. With the adoption of EM Technology, less and less tillage is needed as it improves the soils physical properties. Hence, conservation farming can easily be practiced (WAI, 2009).

The use of EM compost made from a free resource, organic waste, has many benefits for soil health and agriculture, whether carried out domestically or as large-scale systems. Effective microorganisms can become established in soil as an associative group of positive interactions. It has been proven that continued use of EM can convert a soil to a truly sustainable type of soil; called a *zymogenic* soil (these soils are dominated by a microflora that can perform useful kinds of fermentations) (Woodward, 2003).

Benefits of EM includes: increased seed protein, crude fat, and seed yield in soybeans; increased N uptake by cowpea from crop residues, control of Sclerotinia in turf grass, increased yields in banana, oranges, peanuts, papayas, mangos; increase efficiency of compost production from three months to three weeks, etc. (Sangakkara, 1990).

### 2.3.3 Compost making with EM

EM compost comprises of organic waste broken down through fermentation. It has higher nutrient level (e.g., nitrogen since ammonia is not released during fermentation). It contains essential nutrients, NPK and other beneficial substances such as vitamins, organic acid, minerals and anti oxidants, which change disease inducing soil to disease suppressive soil, creating favorable environment for beneficial insect and plants to grow healthy (WAI, 2009).

Organic manures are a source of multiple nutrients and can improve soil physical, chemical and biological characteristics. Dinesh *et al.* (2000) reported that soils amended with organic manures consistently registered significantly greater microbial biomass as compared to the unamended soil. Gunadi *et al.* (1999) also reported that the application of vermicompost to tomato and pepper increased the soil bacteria, fungi and actinomycetes. However, the effects of organic manures on crop yield are long term and not immediate, therefore farmers prefer using mineral fertilizers in their cropping systems. Addition of EM together with organic manures is thought to be an effective technique for stimulating supply and release of plant nutrients. Following EM application into the soil there is an increase in soil microorganisms that are beneficial for the growth of the plant (APNAN, 1995).

Specifically the benefits of EM compost are it ferment organic matter opposed to rotting, it is slow release fertilizer, break the organic matter rapidly (Compost ready within 4-6 weeks), it facilitates greater quantity of nutrient, reduce the tendency of pest and diseases transfer and destroy weed seed in the compost through fermentation. It also supplies the 3 major elements NPK, supplies microbes to enhance life in the soil, improve the water holding capacity of the soil, improve the physical property of the soil, create nutrient store house and improvement of soil fertility, carbon supply-source of organic energy and improve soil salinity (WAI, 2009).

Study in India indicated that by using EM technology compost could be prepared in as fast as 3 weeks, compared to a minimum of 3 months using conventional methods. The compost is of very good quality having a good texture and a pleasant odour. Application of EM compost has been to have positive effect on crop production. In peanut crops, the biomass increased by 34%, the density (plant number/square meter) increased by 25%, yield increased by 43%. In soybeans crops, the biomass increased by 40%, the density increased by 69%. Rice yields increased in the first year of application. Maize and sugar cane grew taller by 33%. In Fruits, for mango yields increased by 15%, guava yields doubled, fruit orchards were much healthier (Correa, 2001).

### 2.4 Balanced Fertilization

It is known that at least 16 plant-food elements are necessary for the growth of green plants. These plant-nutrients are called essential elements. In the absence of any one of these essential elements, a plant fails to complete its life cycle, though the disorder caused can, however, be corrected by the addition of that element (Sanjay, 2011).

The majority of farmers active in the food crop sector of developing countries are small-scale farmers who form part of the rural poor. The issue of introducing agricultural systems and improved technologies is particularly important for them since improved productivity provides not only more food but also an income. In order to obtain high yields, fertilizers are needed to supply the crops with the nutrients the soil lacking. With fertilizers, crop yields can often be doubled or even tripled (FAO, 2000).

Balanced use of plant nutrients corrects nutrient deficiency, improves soil fertility, increases nutrient and water use efficiency, enhances crop yields and farmers income, betters crop and environmental quality. To reap the benefits of balanced use of plant nutrients, it is important to have good quality seed, adequate moisture and better agronomic practices with greater emphasis on timeliness and precision in farm operations (Sanjay, 2011).

For good agricultural practices, balanced fertilization primarily means a supply of nitrogen, phosphorus and potassium in line with soil reserves, the requirements and expected yield of the crop, with the addition of magnesium, sulphur and microelements where necessary. Furthermore, fertilizer use integrated into good agricultural practices should provide the needed plant nutrients in sufficient quantities, in balanced proportions, in available form and at the time when the plants require them (FAO, 2000).

Balanced use of fertilizers should be mainly aimed at increasing crop yield, increasing crop quality, increasing farm income, correction of inherent soil nutrient deficiencies, maintaining or improving lasting soil fertility, avoiding damage to the environment, and restoring fertility and productivity of the land that has been degraded by wrong and exploitative activities in the past (Sanjay, 2011).

### 2.5 Combined Use of Organic and Inorganic Fertilizers

Sustained productivity may be achieved through the combined use of various sources of nutrients, and by managing these scientifically for optimum growth, yield and quality of different crops, in a way adapted to local agro-ecological conditions (Hegde, 1997). For sustainable crop production, integrated use of inorganic and organic fertilizer has proved to be highly beneficial. Several literatures and evidences indicated that organic and inorganic fertilizers work best when they are used together. Shalini *et al.* (2002) reported that application of inorganic fertilizer combined with farmyard manure resulted in more vigorous plant growth. The authors also indicated that intensive use of only inorganic fertilizers without organic has created a number of problems which have significantly affected soil fertility and potato productivity. Similarly, Muriithi and Irungu (2004) reported that integrated use of various soil fertility amendment inputs aim at alleviating the limiting nutrients problems and improving their availability from soil reserves.

A field experiment was conducted by Chand *et al.* (2006) to evaluate the influence of combined applications biological and chemical fertility buildup and nutrient uptake in a mint and mustard cropping sequence. The results indicated that integrated supply of plant nutrients played a significant role in sustaining soil fertility and crop productivity. Combined application of organic and inorganic fertilizers help to improve the physico-chemical properties as well as biological properties of soils (Daniel, 2006). Sendur *et al.* (1998) summarized that application of organic manures (FYM, vermicompost, neem cake) combined with recommended dose of inorganic fertilizers showed superior performance in growth and fruit yield of tomato.

Integrated nutrient management on commercial vegetables studied by Patil (1995) revealed that the combination of recommended dose of inorganic fertilizer and recommended dose of vermi compost recorded significantly higher number of tomato fruits per plant and average fruit weight over absolute control, recommended dose of inorganic fertilizer, FYM and vermi compost alone but was on par with combined application of organic and inorganic fertilizers. Reddy *et al.* (2002) also reported that the average fruit weight in tomato was highest in treatments that combined farm yard manure + recommended dose of fertilizer while the lowest was recorded from plants which were fertilized either with farm yard manure or vermicompost alone. Paulraj *et al.* (1982) reported that application of NPK along with recommended dose of FYM registered the highest fruit yield of tomato as compared to the control, in red sandy loam soil of madurai. Malik *et al.* (2011) also reported that integration of farmyard manure and inorganic sources exhibited an increase in yield and yield related attribution of capsicum. Patil *et al.* (2004) also reported that average fruit weight was found to be better when 50 % recommended dose of fertilizer and 50 % farm yard manure were applied together.

## 2.6 Chemical Composition of Coffee Pulp

Coffee pulp is the first product obtained during processing, and represents 40-42% of the whole berry on dry weight basis (Wintgon, 2004). Wet processed coffee pulp contain 5.6% lignin and 30 and 26% neutral and acid detergent fiber respectively indicating that it has much higher feed value compared to dry processed pulp. The anti-physiological component of wet processed coffee pulp is also lower than that of the dry processed coffee pulp (Getachew *et al.,* 1989). However, wet processed coffee pulp as recovered from the processing installations is high in moisture content (70%) and does not store well. The presence of protein, sugars, minerals and high water contents of wet processed coffee pulp makes it an excellent substrate for the growth of microorganisms and fast rate of spoilage (Pandey *et al.*, 2000).

### 2.7 Nutrient Requirements of Tomato Plant

It is a well known fact that adequate fertilizer is required by tomato for growth and high yield. The fertilizer does this through its ability to replenish the soil with nutrients that are lacking in the soil. As a result of this, adequate levels of nutrients are very vital to increasing the production and yield of tomato (Ogbomo and Egharevba, 2009). The quantity of nutrients to be applied depends on the yield potential of the cultivar, the level of available nutrients in the soil, and growing conditions (Hegde, 1997).

Of the major nutrients, nitrogen is often required in the greatest quantity by crops, primarily for vigor and yield. Nitrogen plays a key role in chlorophyll production and protein synthesis (Moigradean, 2007). High fertilizer N rates may increase plant growth (Andersen *et al.* 1999; Tei *et al.* 2002), decrease tomato fruit color (Seliga and Shattuck 1995), increase the amount of green fruit at harvest and increase susceptibilities to blossom-end rot and diseases (Herrero *et al.* 2001). On the other hand, under-fertilization with N may reduce yield and quality (Tremblay *et al.* 2001).

Tomatoes need moderate to high levels of P and K. On deficient soils, most needs be supplementary P and K as indicated by soil test results. Potassium is a particularly important nutrient for tomatoes (Diver, 2005). Phosphorus is a vital component of adenosine triphosphate (ATP) which supplies the energy for many processes in the plant. Phosphorus rarely produces spectacular growth responses, but is fundamental to the successful development of all crops. Potassium (K) is needed by virtually all crops and often in higher rates than nitrogen. Potassium regulates the plant’s water content and the expansion. It is key to achieving good yield and quality in cotton and critical for increasing the size, juice content and sweetness of fruit (Moigradean, 2007).

# 3 MATERIALS AND METHODS

## 3.1 Description of Experimental Site

The experiment was conducted during 2010/2011 cropping season under irrigation at College of Agriculture and Veterinary Medicine (JUCAVM) horticultural farm, Jimma University. The site is located 346 km southwest of Addis Ababa lies at $7^0$, 33' N latitude and $36^0$, 57' E longitude at an altitude of 1710 m.a.s.l. The area receives an annual rainfall of 1500mm. The mean maximum and minimum temperatures are $26.8^0$C and $11.4^0$C, respectively and the mean maximum and minimum relative humidity are 91.4% and 39.92% respectively (BPEDORS, 2000). The soil contained 4.07% organic matter, total nitrogen 0.16%, available phosphorus 228.9 ppm, 1.15 meq/100g of soil potassium and 14.66 meq/100g of soil CEC.

## 3.2 Treatments and Design

A 2 x 10 factorial experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The treatment combinations consisted of Factor A (Variety) with two levels and Factor B (Fertilizer) with ten levels. There were 20 treatment combinations and a total of 60 experimental units.

**Factor A: Varieties**

The varieties used for this particular study were two commonly grown tomato varieties (Bishola (V1) and Fetane (V2)) (Table 1). According to research conducted in 2009/2010 at JUCAVM to evaluate nine tomato cultivars (including Fetane and Bishola) for their growth, yield and quality from the determinate varieties these two varieties performed best for the research area Menberu (2011) and based on that the two varieties are selected for this particular research. The seeds of the varieties were obtained from Melkassa Agricultural Research Center (MARC).

Table 1 List of Varieties and Their Description

| Variety name | Year of release | Area of adaptation (altitude) | Growth habit | Unique characteristics | Maturity (days | Yield (t/ha) |
|---|---|---|---|---|---|---|
| Fetane | 2005 | 700-2000 | Determinate | Concentrated fruit set, hard fruits, earliness and high yield | 78-80 | 45.4 |
| Bishola | 2005 | 700-2000 | Determinate | Large fruit size, green shoulder fruit color before maturity | 85-90 | 34 |

Source: - (MoARD, 2005)

**Factor B: Fertilizer**

The composting material used here (coffee pulp) was obtained from Limu Coffee Plantation and the inorganic fertilizers (urea and DAP) were commonly used forms of inorganic fertilizers by the small-scale farmers and commercial growers in the country. The whole amount of DAP was applied at transplanting whereas urea was given at two equal splits (half at transplanting and the rest half 30 days after transplanting) as basal application.

EM compost at the rate of 10t/ha (5.88kg/plot) (WAI, 2009), conventional compost at the rate of 10t/ha (5.88kg/plot) and inorganic fertilizers at the rate of 200kg/ha (0.1176kg/plot) DAP and 150kg/ha (0.0882kg/plot) Urea were applied in the following proportions.

$F_0$ = Control (with no fertilizer applied)

$F_1$ = Full dose of recommended Inorganic Fertilizer (IF) alone

$F_2$ = Conventional Compost (CC) alone

$F_3$ = Effective Microorganism Treated Compost (EMTC) alone

$F_4$ = ¼ Effective Microorganism Treated Compost + ¾ recommended IF

$F_5$= ½ Effective Microorganism Treated Compost + ½ recommended IF

$F_6$= ¾ Effective Microorganism Treated Compost + ¼ recommended IF

$F_7$=¼ Conventional Compost + ¾ recommended IF

$F_8$=½ Conventional Compost + ½ recommended IF

$F_9$=¾ Conventional Compost + ¼ recommended IF

### 3.3 Procedure for Coffee pulp Compost Preparation

The materials used in the composting are coffee pulp obtained from Lemu Coffee Plantation and activated EM solution (2 liters/ton of coffee pulp) and top soil. For compost preparation two heap contains previously recommended coffee pulp compost (90% coffee pulp+10% top soil) treated with and without EM.

Materials for EMAS (Effective microorganisms Activated Solution) were EM stock solution, molasses, water, air tight plastic container, plastic tube of small diameter (for letting air out of plastic container) and a small bottle filled with water into which the other end of an outlet tube is placed. The proportion of the mix was 5 % EM stock solution, 5 % molasses and 90% water (WAI, 2009). The mixture was kept under shade for 2 weeks. EMAS were ready for use when it produced a sweet fermented smell and a pH value of less than four. EM was sprayed in between the materials. The presence of ‘fire fungi’ (white) indicates that the heap is too dry and so more water is required.

The Windrow composting method (the production of compost by piling biodegradable waste) was used. Nine cubic meter (1 tone) piles coffee pulp was piled into 3m long heaps about 1m high, 1m wide at the top and 1.5m at the base and covered with plastic sheet and managed properly.

Turning of compost was important as it ensures proper mixing, wetting, aeration and decomposition. The piles aeration was maintained by turning the heap once a week by manual turning. The compost heap was turned using pitchforks. Materials at the bottom were then placed at the top of the heap. Fifty percent moisturizing with water was needed on the heap during turning particularly when conditions are dry. Compost turning was continued until the heaped materials turn dark gray (Misra, 2003).

Seeds were sown in rows spaced at 15cm apart on $1x2m^2$ raised nursery bed and seedlings were transplanted after 6 weeks to a 5.88 $m^2$ experimental plot to accommodate 28 plants per plot (four rows) at a spacing of 70cm between rows and 30 cm between plants. The spacing between plots in each replication and adjacent replications was 0.5 meter and 1 meter, respectively. All management practices, other than the planned treatments were applied uniformly to all the plots.

## 3.4 Data Collected

Data were collected from the two middle rows excluding the border. Individual parameters were recorded from ten randomly taken plants in the middle rows.

### 3.4.1 Growth Parameters:

1. **Plant height (cm):** plant height of ten randomly selected plants was measured from the ground level to the highest point at blooming stage and the mean was recorded in cm.

2. **Number of primary Branches per Plant**: the actual counting of the number of branches on the main stem of ten randomly selected plants was made at red ripe stage.

3. **Days to 50% flowering:** This was accomplished by recording the number of days from date of transplanting to the date on which about 50% of the plants in a plot produced flowers.

4. **Number of Flower Clusters per Plant:** The total number of flower clusters per plant was counted from each pre-tagged plants in each plot at physiological maturity.

5. **Number of Flowers per Cluster**: Selected flower clusters from pre-tagged plants in each plot were tagged from lower, middle and upper clusters and the mean number of flowers per cluster was computed.

6. **Fruit Set Percentage (%):** This was obtained by dividing the number of fruits by the number of flowers per cluster and means from lower, middle and upper part were used for the computation.

7. **Days to Fruit Maturity:** This is accomplished by counting the actual number of days from transplanting to the date on which more than 50% of the plants attained fruit maturity on the harvestable rows of the plot.

8. **Harvest duration (days):** This was computed as the number of days taken starting from the first to the final picking of fruits from each plot.

9. **Number of harvests:** These data were recorded as the number of harvests starting from first picking to final picking.

**3.4.2 Yield and Yield Components**:

1. **Number of Fruits per Cluster**: The total number of fruits per clusters was counted from each pre-tagged plants in each plot having three labels hung on lower, middle, and upper part at physiological maturity.

2. **Fruit length (mm)**: Average length (from stem end to blossom end) of ten randomly taken ripe fresh fruits of the first harvest was taken randomly from five plants per plot were measured by caliper and values are given in mm.

3. **Fruit diameter (mm)**: Average diameter at the widest point of ten randomly taken ripe fresh fruits of the first harvest is taken randomly from five plants per plot were measured by caliper and the values are given in mm.

4. **Average Fruit Weight per plant** (g/plant): It was done by measuring the weight of 10 fruits per sampled plant and recording the average in gram per plant.

5. **Fruits per plant**: number of fruits per plant counted and averaged from each plot on ten randomly selected plants.

6. **Total Fruit Yield per plant** (g/plant): this was measured from sampled plants by taking the mean weight of fruit in successive harvests per plant and expressed in terms of gram per plant.

7. **Total Fruit Yield per hectare** (t/ha): the mean total yield per hectare was obtained by the summation of marketable and unmarketable fruit yield and expressed in terms of tones.

8. **Marketable Fruit Yield per hectare** (t/ha): At each harvest time, fruits were categorized based on visual observations of their physical appearance. Fruits, which were free of damage, were considered as marketable and expressed in terms of tones per hectare.

9. **Unmarketable Fruit Yield per hectare** (t/ha): During successive harvest, unmarketable fruits were sorted, based on visual observations of their physical appearance. Fruits, which were cracked, damaged by insect, physically disordered fruits, diseased etc., were considered as unmarketable fruit.

**3.4.3 Quality Parameters**

1. **Fruit Shape Index**: This is calculated by taking the ratio of fruit length and fruit diameter.

2. **Fruit Pericarp thickness (mm)**: Ten randomly taken fruits were dissected and their pericarp thickness measured from the equatorial section using a Vernier caliper and the values are expressed in mm.

3. **Number of seeds per fruit:** Number of seeds obtained from ten randomly selected fruits of the sample plants in each plot was counted and averaged to get seed number per fruit.

4. **Seed Weight per fruit (g):** Seeds separated from ten randomly selected fruits, washed and weighed to calculate the weight of seeds per fruit and expressed in gram

5. **Pulp Weight per fruit (g):** The pulp of ten fruits was extracted and weighed after excluding the seeds with sieve and the values expressed in grams.

6. **Juice Volume (ml):** The juice of ten randomly taken ripe fruits from each replication was extracted using a juice extractor. The volume of extracted juice was then measured using a graduated glass cylinder and the values expressed in milliliter of juice.

7. **Pulp to seed ratio:** The ratio between the weight of pulp and that of the seeds worked out from ten randomly taken fruits from each plot.

8. **Titratable Acidity (%**citric acid**):** To determine the titratable acidity of the sample fruits aliquot of tomato juice was extracted using a juice extractor and the extracted juice was filtered using a cheese cloth. Then 10ml clear tomato juice was titrated with 0.1N NaOH to an end point (pink color) (Meseret, 2010). The Titratable acidity expressed as percent citric acid was obtained from the following formula (Meseret, 2010):

$$TTA\ (\%) = \frac{TITRE*0.1NaOH*0.64}{1000}*100$$

9. **Total Soluble Solid ($^0$Brix):** To determine the TSS of the sample fruits aliquot of juice was extracted using a juice extractor and the extracted juices were filtered using cheesecloth. The TSS was determined by refractormeter (Bellingham + Stanley 45-02 BS eclipse) by placing 1 to 2 drops of clean juice on the prism. Between samples, the prism of the Refractrometer was washed with distilled water and dried before use.

### 3.4.4 Soil parameters

Representative soil samples were collected at 0-30 cm depth using an auger from randomly selected spots of the entire experimental field and composited in to three samples i.e. one composite sample from four samples of a uniform area. Then, the composited samples were dried and passed through 2.0 mm sieve before laboratory analysis and all the soil related data were done. Moreover, soil samples were taken from each experimental plot at final harvest to determine the basic physico-chemical properties and soil microbial status.

1. **Soil pH**: The soil was analyzed for pH by using digital pH meter (Hanna Instruments, 2006) using pure water (1:1 ratio).
2. **Organic Carbon:** organic carbon content of the soil was determined based on oxidation of organic carbon with acid dichromate medium following the

Walkley and Black method as described by Dewis and Freitas (1970).

3. **Total Nitrogen (N):** was analyzed using the Kjeldahl digestion, distillation and titration method as described by Black (1965) by oxidizing the OM in concentrated sulfuric acid solution (0.1N $H_2SO_4$).
4. **Cation Exchange Capacity (CEC): C**EC was determined by ammonium acetate method (Chapman, 1965).
5. **Available Phosphorus (P):** Available phosphorous was determined using standard procedure of Bray II method.
6. **Potassium (K):** Potassium was determined using flame photometer (Rowell, 1994).
7. **Organic matter (OM):** The Walkley and Black (1934) wet digestion method was used to determine soil OM.
8. **Soil Microorganisms**: Soil samples for microbiological analysis were taken from the top 15cm depth during the final harvest. Nutrient Agar and PDA (Potato Dextrose Agar) media were used to grow bacteria and fungi respectively and the number of colonies per gram (CFU/g) was calculated by multiplying plate count with the dilution factor in laboratory using dilution plate method (Kapoor and Shashi, 2007).

### 3.5 Data Analysis

Data were first checked for meeting all assumption and subjected to Analysis of Variance (ANOVA) by using SAS Computer Software version 9.2 (SAS Institute Inc., 2008). When ANOVA showed significant differences, mean separation was carried out using LSD (Least Significant difference) test at 5% level of significance.

# 4 RESULTS AND DISCUSSION

Data on growth, yield, and quality parameters were recorded during the course of the study. Significant differences between varieties, fertilizer and their interactions were observed for most of the parameters tested and the results of the experiment are presented and discussed as follows.

## 4.1 Growth Parameters

### 4.1.1 Plant height

The result of this experiment indicated that the interaction of variety with fertilizer showed a highly significant ($P<0.01$) effect on plant height of tomato (Table 2 and Appendix Table 1). Significantly the highest ($p<0.05$) plant height (66.97 cm) was recorded from Bishola that received full dosage of IF followed by Bishola fertilized with ¼ EMTC plus ¾ IF (61.03cm), Fetane which was treated with full dose of IF (60.50) and Bishola that received ½ EMTC plus ½ IF (59.70 cm). On the other hand, the lowest plant height (39.7cm) was recorded from Fetane that received no fertilizer (control).

The general observation also illustrates that all the treatments recorded better plant height over the control. For both varieties, treatments with more proportion of inorganic fertilizer gave higher plant height than lower proportion of inorganic fertilizer or the control. This might be due to the rapid availability of nutrients from the applied inorganic fertilizers since they provide major elements at the early stage of plant growth and development. Thus, plants exhibited accelerated growth rate than compost treated plants. In addition, the EMTC treated plants showed highest plant height over those treated with conventional compost. These results are in line with the findings of Meherunnessa *et.al.* (2011) who reported that tomato plants fertilized with full inorganic fertilizer produced the highest plant height than compost treatments.

### 4.1.2 Number of primary branches per plant

A very highly significant ($p<0.001$) interaction effect of variety with fertilizer was observed for number of primary branches per plant (Table 2 and Appendix Table 1). The maximum number of primary branches (8.00) was observed from the Fetane that received full dose of IF followed by Fetane with ¼ EMTC plus ¾ IF (7.13). On the contrary, the lowest (4.80) number of primary branch per plant was recorded from Bishola that received no fertilizer followed by Bishola with full CC (5.07) and Fetane with no fertilizer (5.20).

Table 2. Interaction effect of variety and fertilizer on plant height, number of primary branches, days to 50 % flowering, flower clusters per plant and flowers per cluster of tomato in Jimma

| Variety | Fertilizer | Plant height (cm) | Number of primary branches | Days to 50 % flowering | Flower clusters per plant | Flowers per cluster |
|---|---|---|---|---|---|---|
| Bishola | Control | $42.60^{m}$ | $4.80^{m}$ | $26.67^{i}$ | $3.00^{j}$ | $3.02^{l}$ |
| | Full IF | $66.97^{a}$ | $6.80^{c}$ | $37.00^{a}$ | $10.00^{b}$ | $4.00^{g}$ |
| | Full CC | $51.97^{g}$ | $5.07^{l}$ | $28.00^{h}$ | $4.00^{i}$ | $3.42^{k}$ |
| | Full EMTC | $54.00^{ef}$ | $5.40^{k}$ | $28.33^{gh}$ | $5.00^{h}$ | $3.53^{jk}$ |
| | ¼ EMTC + ¾ IF | $61.03^{b}$ | $6.43^{d}$ | $37.00^{a}$ | $9.00^{c}$ | $5.62^{b}$ |
| | ½ EMTC + ½ IF | $59.70^{b}$ | $6.20^{e}$ | $33.00^{d}$ | $8.00^{d}$ | $3.91^{gh}$ |
| | ¾ EMTC + ¼ IF | $57.70^{c}$ | $6.03^{fg}$ | $35.00^{b}$ | $7.00^{e}$ | $4.44^{e}$ |
| | ¼ CC + ¾ IF | $55.93^{cd}$ | $5.87^{hi}$ | $31.00^{e}$ | $6.00^{f}$ | $3.78^{hi}$ |
| | ½ CC + ½ IF | $55.23^{de}$ | $5.77^{hi}$ | $31.00^{e}$ | $6.00^{f}$ | $3.64^{ij}$ |
| | ¾ CC + ¼ IF | $54.63^{def}$ | $5.57^{j}$ | $30.00^{f}$ | $5.00^{h}$ | $3.56^{jk}$ |
| Fetane | Control | $39.70^{n}$ | $5.20^{l}$ | $26.33^{i}$ | $4.00^{i}$ | $3.43^{k}$ |
| | Full IF | $60.50^{b}$ | $8.00^{a}$ | $35.00^{b}$ | $12.00^{a}$ | $5.07^{c}$ |
| | Full CC | $43.83^{lm}$ | $5.53^{jk}$ | $27.00^{i}$ | $5.00^{h}$ | $3.81^{ghi}$ |
| | Full EMTC | $45.40^{kl}$ | $5.73^{i}$ | $27.00^{i}$ | $5.70^{g}$ | $3.97^{gh}$ |
| | ¼ EMTC + ¾ IF | $56.03^{cd}$ | $7.13^{b}$ | $34.00^{c}$ | $10.00^{b}$ | $6.20^{a}$ |
| | ½ EMTC + ½ IF | $53.37^{fg}$ | $6.83^{c}$ | $33.33^{cd}$ | $9.00^{c}$ | $4.87^{d}$ |
| | ¾ EMTC + ¼ IF | $49.97^{h}$ | $6.40^{d}$ | $30.33^{ef}$ | $8.00^{d}$ | $5.80^{b}$ |
| | ¼ CC + ¾ IF | $49.10^{hi}$ | $6.13^{ef}$ | $29.00^{g}$ | $7.00^{e}$ | $4.78^{d}$ |
| | ½ CC + ½ IF | $48.17^{ij}$ | $5.90^{gh}$ | $28.00^{h}$ | $6.00^{f}$ | $4.69^{d}$ |
| | ¾ CC + ¼ IF | $47.03^{jk}$ | $5.83^{hi}$ | $28.00^{h}$ | $6.00^{f}$ | $4.19^{f}$ |
| LSD (5%) | | 1.71 | 0.14 | 0.14 | 0.79 | 0.21 |
| CV (%) | | 2 | 1.4 | 1.4 | 1.6 | 1.9 |

*Means followed by the same letter within the same column are not significantly different at 5% level of significance.*

*Where: IF= inorganic fertilizer, CC= conventional compost and EMTC= effective microorganism treated compost*

The observed maximum number of primary branches per plant from Fetane that received full dose of IF might be the result of combined effect of responsiveness of the variety and the readily available nutrient in the soil. This can be related to the application of full or more proportion of inorganic fertilizer that could be used for the early growth of the plant.

This result is harmony with the result of Ogbomo (2011) who reported that number of primary branches is influenced positively by fertilizer application.

Contrary to this result, Chanda *et al.* (2011) reported only organic fertilizer treated tomato plants showed more branching than inorganic fertilizer treated plants. Nandani (2006) also reported the highest number of branches was recorded in 50% organic and 50% inorganic fertilizer.

### 4.1.3 Days to 50% flowering

The analysis of variance for the interaction effect of variety with fertilizer showed very highly significant ($p<0.001$) difference on days to 50% flowering (Table 2 and Appendix Table 1). The minimum number of days (26.33) to achieve 50% flowering was recorded from Fetane that received no fertilizer followed by Bishola treated with full dose of IF (26.67 days), Fetane fertilized with full CC (27 days) and Fetane that received full EMTC (27 days) and they were not significantly different from Fetane that received no fertilizer. Bishola that received full dose of IF and ¼ EMTC plus ¾ IF respectively took the maximum number of days (37) to reach 50% flowering, which is longer by 11 days than the earliest flowering. Generally, the control treatments (both varieties with no fertilizer application) flowered earlier which might be attributable to the nutrient stress during the early growing period, which in turn lead plants to complete their life cycle shortly. This result is contrary with the finding of Ogbomo (2011) who reported that tomato plants treated with full NPK and organic + inorganic fertilizers showed the most significant earliness to 50% flowering than other treatments. Jagadeesha (2008) also reported that RDF + biofertilizers were found to be superior for earliness in days to 50 per cent flowering.

### 4.1.4 Flower clusters per plant

The interaction effect of variety with fertilizer on the number of flower clusters per plant was found to be very highly significant ($p<0.001$) (Table 2 and Appendix Table 1). The number of flower clusters per plant ranged from 3, which was recorded from Bishola grown with no fertilizer, to 12 which was registered from Fetane that received full dose of

IF followed by Bishola which was cultivated with full dose of IF and Fetane fertilized with ½ EMTC plus ½ IF (10). Though no apparently significant differences were observed, in general, the highest number of flower clusters per plant was registered from the treatments that received more proportion of IF and all those treatment combinations with EMTC resulted in more flower clusters over the conventional compost.

This result is in line with the findings of Sung and Lee (2010) who reported that application of EM to tomato field shows increase in number of flower clusters. Meherunnessa *et al.* (2011) also reported that organic and inorganic fertilizers significantly contribute for producing higher number of flower clusters per plant. Krishna and Krishnappa (2001) studied the Growth and yield of tomato in relation to inorganic fertilizers and organic manures and found that combined application of organic and inorganic sources of fertilizers helped to produce more number of flower clusters. The number of flower clusters per plant was very strongly and positively correlated with the number of primary branches per plant (r=0.97***) indicating that the more number of primary branches, the more the number of flower clusters per plant.

### 4.1.5 Number of Flowers per cluster

The number of flowers per cluster was very highly and significantly ($p<0.001$) affected by the interaction between variety and fertilizer (Table 2 and Appendix Table 1). The mean number of flowers per cluster ranged from 3.02 recorded from Bishola with no fertilizer application to 6.2 recorded from Fetane that received ¼ EMTC plus ¾ IF. Fetane with most of the fertilizer combinations gave more number of flowers per cluster than Bishola. This may be due to the genetic makeup of the varieties. This result is inline with the result of Menberu (2011) who reported that Fetane gave more number of flowers per cluster over Bishola.

### 4.1.6 Days to fruit maturity

There appeared to be a remarkable variation in terms of days to fruit maturity due to interaction effect of variety with fertilizer. The analysis of variance for the interaction effect of variety with fertilizer showed a highly significant ($p<0.01$) difference (Table 3 and Appendix Table 2). The variety Fetane grown with no fertilizer required significantly minimum number of days (60.33) to reach maturity, which however, was not statistically different from Fetane with full EMTC (65.67days) and Fetane with full CC (67.33days). Fertilization of both varieties (Bishola and Fetane) with full dose of IF took the maximum days (79.33 and 78.00) to attain their fruit maturity, which was almost 19 days longer than the minimum number of days to maturity.

Table 3 Interaction effect of variety and fertilizer on days to fruit maturity, number of fruits per cluster and fruit set percentage of tomato in Jimma

| Variety | Fertilizer | Days to fruit maturity | Fruits per cluster | Fruit set percentage |
|---|---|---|---|---|
| Bishola | Control | 68.00[gh] | 1.57[j] | 52.16[f] |
| | Full IF | 79.33[a] | 3.33[e] | 83.33[c] |
| | Full CC | 68.33[fgh] | 2.66[hi] | 77.80[c] |
| | Full EMTC | 70.33[efg] | 2.84[gh] | 80.61[c] |
| | ¼ EMTC + ¾ IF | 75.00[b] | 5.45[ab] | 96.92[a] |
| | ½ EMTC + ½ IF | 75.00[b] | 3.22[ef] | 82.34[c] |
| | ¾ EMTC + ¼ IF | 75.00[b] | 4.11[c] | 92.37[ab] |
| | ¼ CC + ¾ IF | 74.67[bcd] | 3.08[efg] | 81.71[c] |
| | ½ CC + ½ IF | 73.00[bcde] | 2.96[fg] | 81.28[c] |
| | ¾ CC + ¼ IF | 72.00[cde] | 2.88[gh] | 81.10[c] |
| Fetane | Control | 60.33[i] | 1.45[j] | 42.15[g] |
| | Full IF | 78.00[a] | 4.13[c] | 81.44[c] |
| | Full CC | 67.33[h] | 1.72[j] | 45.01[g] |
| | Full EMTC | 65.67[h] | 2.48[i] | 62.50[e] |
| | ¼ EMTC + ¾ IF | 75.00[b] | 5.63[a] | 90.76[b] |
| | ½ EMTC + ½ IF | 74.67[cd] | 3.92[cd] | 80.58[c] |
| | ¾ EMTC + ¼ IF | 72.00[de] | 5.24[b] | 90.29[b] |
| | ¼ CC + ¾ IF | 71.00[ef] | 3.74[d] | 78.24[c] |
| | ½ CC + ½ IF | 68.33[fgh] | 3.35[e] | 71.10[d] |
| | ¾ CC + ¼ IF | 70.33[efg] | 2.85[gh] | 68.06[d] |
| LSD (5%) | | 2.458 | 0.263 | 4.947 |
| CV (%) | | 2.1 | 4.8 | 3.9 |

*Means followed by the same letter within the same column are not significantly different at 5% level of significance.*

*Where: IF= inorganic fertilizer, CC= conventional compost and EMTC= effective microorganism treated compost*

### 4.1.7 Number of Fruits per cluster

The result of this experiment illustrated that the interaction effect of variety with fertilizer on the number of fruits per cluster as a highly significant ($p<0.01$) (Table 3 and Appendix Table 2). The maximum (5.63) number of fruits per cluster was counted from variety

Fetane fertilized with ¼ EMTC plus ¾ IF, which, nonetheless, was not significantly different from Bishola that received ¼ EMTC plus ¾ IF (5.45). To the contrary, the lowest (1.45) number of fruits per cluster was recorded from Fetane that received no fertilizer which however was not significantly different from Bishola grown with no fertilizer (1.58) and Fetane with full CC (1.716). In line with this result, Krishna and Krishnappa (2001) reported that combined application of organic and inorganic sources of fertilizers to tomato plant helped to produce more number of flower clusters and fruits per cluster.

The number of fruits per cluster could be related to the number of flowers per cluster which could be verified by the positive correlations (r=0.92***) between this parameters. This indicates that the higher number of flowers per cluster results in greater number of fruits per cluster.

### 4.1.8 Fruit set percentage

As presented in Table 3 and Appendix Table 2, the interaction effect between variety and fertilizer showed very highly significant ($p<0.001$) difference pertaining to fruit set percentage. Accordingly, the maximum fruit set percentage (96.92%) was observed from variety Bishola fertilized with ¼ EMTC plus ¾ IF followed by Bishola with ¾ EMTC plus ¼ IF (92.37), however, they were not significantly different from each other. The lowest fruit set percentage (42.15) was recorded from Fetane with no fertilizer followed by Fetane that received full dose of CC (44.01%). The results of this experiment indicate that both varieties, which were fertilized with EMTC plus IF, set more percentage of fruits than with the CC plus IF combination. However, tomatoes fertilized with EMTC and CC alone gave the lowest fruit set percentage. All these might be due to the increased nutrient uptake, improved photosynthetic efficiency and increased fertilizer use efficiency due to the application of EM.

This result agrees with the report of Roy (1986) who reported that integrated use of inorganic fertilizer and organic fertilizer improves fruit set percentage of tomato. Rafi *et al*. (2002) studied the effect of organic and inorganic fertilizers on growth and yield of tomato and the maximum fruit set were observed in combined application of 50% RDF + 50% FYM. Nathkumar and Veeraraguvathatham (1999) also reported that the higher fruit set recorded in brinjal plant fertilized with both organic and inorganic sources, than inorganic sources alone.

### 4.1.9 Number of Harvests

The effect of variety and fertilizer independently resulted in a very highly significant ($p<0.001$) difference in respect of the number of harvests. However, the interaction between them revealed no significant ($p>0.05$) effect on the number of harvests (Table 4 and Appendix Table 2). Irrespective of the fertilizer type used, significantly the highest number of harvest (6.17) was exercised from Fetane variety, whereas Bishola required the least (5.23) number of harvest. Since Fetane is superior to Bishola by its number of fruit per plant, it needed more number of picking than Bishola.

Regardless of the variety of tomato planted, the highest number of harvests (7.33) was practiced on tomato plants that obtained the combined application of ¼ EMTC and ¾ IF followed by 1/2 EMTC and ½ IF (6.50). However, the least number of harvests (4.50) was recorded from the control wherein no fertilizer was applied.

From practical point of view, any practice that decreases the number of harvests and duration of harvest has a key role in terms of labor management and reduction of production costs. Therefore, without compromising yield and quality variety Bishola or application of selected fertilizer(s) can help to materialize the same.

### 4.1.10 Harvesting duration

The harvesting duration, which is the time from first to the last harvesting day, was found to be very highly and significantly ($p<0.001$) affected by variety and fertilizer (Table 4 and Appendix Table 2). However, the interaction effect of fertilizer with variety did not show significant influence on the duration of harvest. Plots treated with 1/3 EMTC plus ¾ IF took longest (28 days) harvest duration followed by plots fertilized with ½ EMTC plus ½ IF (27.67days). Statistically similar with 1/3 EMTC plus ¾ IF. Harvesting was completed with few harvests and hence the control plots exhibited the shortest harvest duration (18 days). This might basically be due mainly to the nutrient deficiency in the soil that enhanced the growth cycle of the plants to bulk their fruits within few days time. Generally, all fertilizer treatments took longer duration over that of the control. Regarding the varieties, Bishola took longer harvesting duration (24.53 days) than Fetane (22.33days). This result is in accordance with the report of Meseret (2010).

Table 4 Effect of variety and fertilizer on the number of harvests and harvest duration of tomato in Jimma

| Fertilizer | Number of harvests | Harvest duration (Days) |
|---|---|---|
| Control | 4.50[e] | 20.00[d] |
| Full IF | 5.00[de] | 22.5[bcd] |
| Full CC | 5.50[bcde] | 23.67[b] |
| Full EMTC | 5.66[bcd] | 23.00[bc] |
| ¼ EMTC + ¾ IF | 7.33[a] | 28.50[a] |
| ½ EMTC + ½ IF | 6.50[ab] | 26.67[a] |
| ¾ EMTC + ¼ IF | 6.00[bcd] | 23.50[b] |
| ¼ CC + ¾ IF | 5.33[cde] | 22.00[bcd] |
| ½ CC + ½ IF | 6.16[bc] | 24.00[b] |
| ¾ CC + ¼ IF | 5.00[de] | 20.50[cd] |
| LSD (5%) | 1.00 | 2.435 |
| **Varieties** | | |
| Bishola | 5.23[b] | 24.53[a] |
| Fetane | 6.17[a] | 22.33[b] |
| LSD (5%) | 0.448 | 1.089 |
| CV (%) | 15.1 | 8.9 |

*Means followed by the same letter within the same column are not significantly different at 5% level of significance.*

*Where: IF= inorganic fertilizer, CC= conventional compost and EMTC= effective microorganism treated compost*

## 4.2 Yield Parameters

### 4.2.1 Fruit number per plant

A very highly significant ($p<0.001$) interaction effect of variety with fertilizer was observed for fruit number per plant (Table 5 and Appendix Table 3).

The number of fruits per plant ranged from 8.37 recorded from Bishola that received no fertilizer to 14.53 recorded from Fetane that received ¼ EMTC plus ¾ IF. It is followed by Fetane that received full dose of IF (13.9), Fetane that received ½ EMTC plus ½ IF (13.6), Fetane that received ¾ EMTC plus ¼ IF (13.27) and Fetane that received ¾ CC plus ¼ IF (12.77). The present result is in agreement with the finding of Ncube *et al.* (2011) who reported that EM had a positive effect on fruiting of tomato plants, with the highest number of fruited plants being observed where EM was applied integrated with inorganic fertilizer compared to the compost and inorganic fertilizer treatment. Roy (1986) also reported that integrated use of inorganic fertilizer and organic fertilizer significantly increase number of tomato fruit per plant. Similarly, Ching and Kvonon (1994) reported that application of organic manures + inorganic fertilizers significantly increased the number of fruits per plant and yield of sweet pepper than application of inorganic fertilizers alone. Jagadeesha (2008) reported that application of RDF + biofertilizers recorded higher values for number of fruits per plant, while FYM + without biofertilizers recorded lower values.

The correlation coefficients (Appendix Table 9) showed that, fruit number per plant was strongly and positively correlated with number of primary branches per plant (r=0.90***), number of flower clusters per plant (r=0.89***) and number of fruit per cluster (r=0.75***).

### 4.2.2 Average fruit weight per plant

A significant ($p<0.05$) interaction effect of variety with fertilizer was observed for average fruit weight per plant (Table 5 and Appendix Table 3). The largest and significantly different average fruit weight (138.03 g) per plant was recorded from Bishola treated with ¼ EMTC and ¾ IF followed by Fetane and Bishola fertilized with full dose of IF that registered 124.83g and 119.9g, respectively. For both varieties, the lowest average fruit weight (65.47g for Bishola and 72.5g for Fetane) was recorded from ½ CC and ½ IF, respectively. The lower fruit number of Bishola variety associated with ¼ EMTC and ¾ IF applications resulted in improved average fruit weight of tomatoes than Fetane with the same proportion of fertilizer this may as a result of more assimilates being partitioned to the few fruits formed. This result is in line with the result of Patil (1995) who revealed that the combination of recommended dose of fertilizer and vermicompost recorded significantly higher average fruit weight per plant than recommended dose of fertilizer, farm yard manure and vermicompost alone. Contrary to the present result Ncube *et al.* (2011) reported that sole application of EM resulted in an increase in average fruit weight relative to the application of EM with inorganic fertilizer and inorganic fertilizer with compost treatment.

Table 5. Interaction effect of variety and fertilizer on fruit number plant$^{-1}$, average fruit weight and total fruit yield plant$^{-1}$ of tomato in Jimma

| Variety | Fertilizer | Fruit number plant$^{-1}$ | Average fruit weight (g) plant$^{-1}$ | Total fruit yield (g) plant$^{-1}$ |
|---|---|---|---|---|
| | Control | 8.37$^{o}$ | 97.42$^{cdefg}$ | 335.30$^{m}$ |
| | Full IF | 12.63$^{e}$ | 119.90$^{abc}$ | 744.00$^{c}$ |
| | Full CC | 8.97$^{n}$ | 105.53$^{bcdef}$ | 392.40$^{l}$ |
| | Full EMTC | 9.40$^{mn}$ | 101.58$^{cdefg}$ | 437.80$^{kl}$ |
| | ¼ EMTC + ¾ IF | 11.80$^{fg}$ | 138.03$^{a}$ | 665.20$^{de}$ |
| Bishola | ½ EMTC + ½ IF | 11.20$^{ghi}$ | 109.42$^{bcde}$ | 608.40$^{fg}$ |
| | ¾ EMTC + ¼ IF | 10.60$^{hj}$ | 98.01$^{cdefg}$ | 5620$^{gh}$ |
| | ¼ CC + ¾ IF | 10.10$^{jkl}$ | 114.75$^{bcd}$ | 530.80$^{hi}$ |
| | ½ CC + ½ IF | 9.93$^{klm}$ | 65.47$^{i}$ | 496.80$^{ij}$ |
| | ¾ CC + ¼ IF | 9.33$^{mn}$ | 79.67$^{ghi}$ | 465.40$^{jk}$ |
| | Control | 9.37$^{mn}$ | 73.34$^{hi}$ | 322.00$^{m}$ |
| | Full IF | 13.90$^{b}$ | 106.29$^{bcdef}$ | 895.50$^{b}$ |
| | Full CC | 9.60$^{lmn}$ | 87.80$^{efghi}$ | 401.00$^{l}$ |
| | Full EMTC | 10.33$^{jk}$ | 89.46$^{efgh}$ | 475.50$^{jk}$ |
| | ¼ EMTC + ¾ IF | 14.53$^{a}$ | 124.83$^{ab}$ | 1026.10$^{a}$ |
| | ½ EMTC + ½ IF | 13.60$^{bc}$ | 94.32$^{defgh}$ | 737.30$^{c}$ |
| Fetane | ¾ EMTC + ¼ IF | 13.27$^{cd}$ | 90.88$^{efgh}$ | 711.50$^{cd}$ |
| | ¼ CC + ¾ IF | 12.77$^{de}$ | 82.87$^{fghi}$ | 684.40$^{de}$ |
| | ½ CC + ½ IF | 12.17$^{ef}$ | 72.50$^{hi}$ | 649.70$^{ef}$ |
| | ¾ CC + ¼ IF | 11.20$^{h}$ | 90.97$^{efgh}$ | 580.50$^{g}$ |
| LSD (5%) | | 0.59 | 20.26 | 45.98 |
| CV (%) | | 3.2 | 12.6 | 4.7 |

*Means followed by the same letter within the same column are not significantly different at 5% level of significance.*

*Where: IF= inorganic fertilizer, CC= conventional compost and EMTC= effective microorganism treated compost*

### 4.2.3 Total fruit yield per plant

The analysis of variance for the interaction effect of variety and fertilizer showed a very highly significant ($p<0.001$) difference on fruit yield per plant (Table 5 and Appendix Table 3). The total fruit yield per plant ranged from 322 g, recorded from Fetane that received no fertilizer to 1026.1 g obtained from Fetane grown with 1/4 EMTC plus ¾ IF followed by Fetane with full dose of IF and Bishola with full IF, which produced 895.5 and 744g, respectively. As the proportion of IF applied increased, so did the fruit yield per plant. Moreover, EMTC plus IF showed better yield over CC plus IF. Even though Bishola variety has a larger fruit size, Fetane was superior in terms of number of fruits per plant as a result of which it gave more fruit yield per plant. In line with this Rafi *et al.*

(2002) reported that the highest yield in terms of yield per plant and yield per hectare basis was recorded with the application of 50% RDF + 50% FYM.

### 4.2.4 Total fruit yield

The analysis of variance for the interaction effect of variety with fertilizer showed a very highly significant ($p<0.001$) difference on total fruit yield tone $ha^{-1}$ (Table 6 and Appendix Table 3). The highest and significantly different total fruit yield per hectare (47.92 t/ha) was recorded from Fetane that received ¼ EMTC plus ¾ IF followed by Fetane that received full dose of IF, Fetane that received ½ EMTC plus ½ IF and Bishola that received full dose of IF which is 37.38, 35.13 and 34.79 t respectively. The lowest total fruit yield per hectare for both varieties was obtained from control treatment (13.92 t for Bishola and 15.71 t for Fetane). Even though it is greater than the control, EMTC and IF alone gave the lowest total fruit yield per hectare. From this, we can see that IF and EMTC combination gave better yield than CC and IF combination.

Application of EM with inorganic fertilizer in this case resulted in an increase in yield over EMTC and CC alone, demonstrating that EM is more effective when integrated with inorganic fertilizer. The reasons for higher yields from integrated application of EM and inorganic fertilizer treated plots were possibly the favorable conditions for decomposition, since effective microorganisms make use of the chemical fertilizer more effective and reduce losses. The two fertilizers worked more efficiently and released more plant nutrients, which ultimately resulted in the increased fruit yield.

From this, it can be concluded that combined (inorganic and organic fertilizer) application supplies the nutrients continuously and rapidly. This result is in agreement with the finding of Meherunnessa *et al.* (2011). They observed that treatment with organic compost + inorganic fertilizer resulted in the highest yield (28.61 t/ha). Khaliq *et al.* (2006) also reported that application of organic materials or EM alone did not significantly increase yield. However, their integrated use resulted in a 44% increase in yield over the control. Contrary to present result Ncube *et al.* (2011) reported that highest and significantly different fruit yield were recorded from full inorganic fertilizer and sole application of EM or its application with compost, inorganic fertilizer or both, resulted in yield decreases.

Table 6 Interaction effect of variety and fertilizer on total and marketable fruit yield of tomato in Jimma

| Variety | Fertilizer | Total fruit yield ($tha^{-1}$) | Marketable fruit yield ($tha^{-1}$) |
|---|---|---|---|
| Bishola | Control | $13.92^{o}$ | $9.25^{m}$ |
| | Full IF | $34.79^{c}$ | $30.25^{cd}$ |
| | Full CC | $19.15^{m}$ | $14.64^{k}$ |
| | Full EMTC | $21.14^{l}$ | $16.69^{k}$ |
| | ¼ EMTC + ¾ IF | $31.76^{ef}$ | $27.21^{ef}$ |
| | ½ EMTC + ½ IF | $28.65^{gh}$ | $24.00^{gh}$ |
| | ¾ EMTC + ¼ IF | $26.52^{ij}$ | $22.20^{hi}$ |
| | ¼ CC + ¾ IF | $24.96^{jk}$ | $20.58^{ij}$ |
| | ½ CC + ½ IF | $23.88^{k}$ | $19.70^{j}$ |
| | ¾ CC + ¼ IF | $20.76^{lm}$ | $15.75^{k}$ |
| Fetane | Control | $15.71^{n}$ | $11.57^{l}$ |
| | Full IF | $37.38^{b}$ | $32.73^{b}$ |
| | Full CC | $19.78^{lm}$ | $15.79^{k}$ |
| | Full EMTC | $23.45^{k}$ | $19.30^{j}$ |
| | ¼ EMTC + ¾ IF | $47.92^{a}$ | $44.01^{a}$ |
| | ½ EMTC + ½ IF | $35.13^{c}$ | $31.54^{bc}$ |
| | ¾ EMTC + ¼ IF | $33.64^{cd}$ | $29.70^{cd}$ |
| | ¼ CC + ¾ IF | $32.72^{de}$ | $29.00^{de}$ |
| | ½ CC + ½ IF | $30.11^{fg}$ | $25.95^{fg}$ |
| | ¾ CC + ¼ IF | $28.12^{hi}$ | $24.51^{g}$ |
| LSD (5%) | | 1.68 | 2.13 |
| CV (%) | | 3.7 | 5.5 |

*Means followed by the same letter within the same column are not significantly different at 5% level of significance.*

*Where: IF= inorganic fertilizer, CC= conventional compost and EMTC= effective microorganism treated compost*

### 4.2.5 Marketable fruit yield

The analysis of variance for the interaction effect of variety with fertilizer showed a very highly significant ($p<0.001$) difference on marketable yield tone per hectare (Table 6 and Appendix Table 3). The highest and significantly different marketable fruit yield (44.01 t/ha) was recorded from Fetane that received ¼ EMTC plus ¾ IF followed by full dose of IF and Fetane that received ½ EMTC plus ½ IF which gave 32.73 and 31.54 t/ha marketable yield per hectare respectively. From all the fertilizer combination treatments that had more amount of inorganic fertilizer gave highest yield. Fetane variety with most of the fertilizer combination gave the highest marketable fruit per hectare than Bishola. This may be because Fetane variety recorded more number of fruit per plant and unit area than Bishola and during the experiment period Bishola variety were damaged by radial cracking due to its bigger fruit size.

The correlation coefficients (Appendix Table 9) revealed that, marketable fruit yield was very highly significant and strongly and positively correlated with total yield per hectare (r=0.99***), total yield per plant (r=0.97***), number of fruits per plant ($r=0.96^{***}$), number of fruits per cluster (r=0.74***), primary branches per plant (r=0.95***) and fruit length ($r=0.83^{***}$). In line with this result, Menberu (2011) and Balibrea *et al.* (1997) indicated that tomato fruit yield was strongly influenced by number of fruits per cluster and number of fruits per plant. Sendur *et al.* (1998) summarized that application of organic manures (FYM, vermicompost, neem cake) combined with recommended dose of inorganic fertilizers showed superior performance in fruit yield of tomato.

### 4.2.6 Unmarketable fruit yield

The effect of variety showed a very highly significant (p<0.001) difference on unmarketable yield tone per hectare (Table 7 and Appendix Table 3). The highest (4.53t/ha) unmarketable fruit yield tone per hectare was recorded from Bishola variety. The unmarketable yield was accounted mainly by diseases, physiological disorders, and excessively small fruits, in this case mainly Late Blight, Septoria Leaf Spot, radial cracking and Blossom End Rot. Even thought the disease (Late blight and septoria leaf spot) which is very common on the growing area affect all the plots; plots having Bishola variety results more unmarketable yield. This could be due to the growth habit of the fruit (shoulder shape and size) in which the fruit shoulder shape is moderately depressed and the diameter of the fruit is wider which leads to radial cracking of the fruit during maturity. Effect of fertilizer and their interaction effect with variety shows non-significance effect.

The correlation coefficients reveled that unmarketable yield was positively correlated with fruit diameter (r=0.30*) and fruit pericarp thickness (r=0.34*). A negative and loose correlation was detected with fruit shape index (r=-0.38*).

Table 7 Effect of variety on unmarketable yield tone per hectare

| Varieties | Unmarketable yield t $ha^{-1}$ |
|---|---|
| Bishola | 4.53[a] |
| Fetane | 3.98[b] |
| LSD (5%) | 0.29 |
| CV (%) | 13 |

*Means followed by the same letter within the same column are not significantly different at 5% level of significance.*

## 4.3 Quality Response Variables

### 4.3.1 Fruit length and fruit diameter

A very highly significant ($p<0.001$) interaction effect of variety with fertilizer was observed for the fruit length per fruit (Table 8 and Appendix Table 4). The longest (7.79 cm) fruit length was recorded from Bishola that received ¼ EMTC plus ¾ IF followed by Fetane which was fertilized with full dose of IF (7.37). On the contrary, the shortest (2.624 cm) fruit length was recorded from the control (Bishola with no fertilizer).

On the other hand, the ANOVA result for the effect of variety and fertilizer showed very highly significant ($p<0.001$) difference on fruit diameter (Table 9 and Appendix Table 4). However, the interaction effect of fertilizer and variety demonstrated no significant impact on fruit diameter. The maximum (7.47 cm) fruit diameter was recorded from plant fertilized with full dose of IF which however was not significantly different from those that received ¼ EMTC plus ¾ IF (7.28cm). On the other hand, the minimum diameter (5.62 cm) was registered from the control treatment. Regarding the varietals differences, the maximum fruit diameter (7.256 cm) was attained by Bishola. This might be because of their fruit shape difference. According to MARD (2009), Fetane has cylindrical shape than Bishola variety which has slightly flattened fruit shape.

Table 8 Interaction effect of variety and fertilizer on fruit length and fruit shape index of tomato in Jimma

| Variety | Fertilizer | Fruit length (cm) | Fruit shape index |
|---|---|---|---|
| Bishola | Control | 2.62[h] | 0.45[e] |
| | Full IF | 7.09[bc] | 0.86[bc] |
| | Full CC | 3.13[h] | 0.50[e] |
| | Full EMTC | 3.96[g] | 0.55[e] |
| | ¼ EMTC + ¾ IF | 7.79[a] | 0.96[bc] |
| | ½ EMTC + ½ IF | 5.82[d] | 0.77[cd] |
| | ¾ EMTC + ¼ IF | 4.49[fg] | 0.59[de] |
| | ¼ CC + ¾ IF | 4.26[g] | 0.62[de] |
| | ½ CC + ½ IF | 4.12[g] | 0.55[e] |
| | ¾ CC + ¼ IF | 4.06[g] | 0.56[e] |
| Fetane | Control | 4.57[fg] | 1.35[a] |
| | Full IF | 7.37[ab] | 1.09[b] |
| | Full CC | 5.05[ef] | 1.06[b] |
| | Full EMTC | 5.42[de] | 1.05[b] |
| | ¼ EMTC + ¾ IF | 6.97[bc] | 1.08[b] |
| | ½ EMTC + ½ IF | 6.62[c] | 1.07[b] |
| | ¾ EMTC + ¼ IF | 5.86[d] | 1.06[b] |
| | ¼ CC + ¾ IF | 5.75[de] | 1.07[b] |
| | ½ CC + ½ IF | 5.63[de] | 1.08[b] |
| | ¾ CC + ¼ IF | 5.39[de] | 1.07[b] |
| LSD (5%) | | 0.641 | 0.196 |
| CV (%) | | 7.3 | 13.6 |

*Means followed by the same letter within the same column are not significantly different at 5% level of significance.*

*Where: IF= inorganic fertilizer, CC= conventional compost and EMTC= effective microorganism treated compost*

### 4.3.2 Fruit shape index

Interaction of varieties with fertilizer imparted a very highly significant ($p<0.001$) effect on fruit shape index (Table 8 and Appendix Table 4). The maximum value for fruit shape index was obtained from Fetane with all fertilizer levels, where as the lowest (0.45) was recorded from Bishola with no fertilizer. All the fertilizer treatments applied to Fetane resulted in no significant effect except Fetane that received no fertilizer from which the highest (1.35) fruit shape index was recorded. However, fertilizer application to Bishola showed a significant effect. The maximum value for fruit shape index attained by the variety Fetane could be due to its large fruit length obtained during the experiment. This study clearly confirmed that fruit shape is directly related to fruit length and diameter, which contributes to better yield and quality of fruit in favor of increasing marketable yield per hectare. In contrary to this result Gossavi (2005) reported that there were no significant differences between organic and inorganic tomato in respect of fruit shape index.

Table 9. Effect of variety and fertilizer on fruit diameter and pulp weight of tomato in Jimma

| Fertilizer | Fruit diameter (cm) | Pulp weight (ml) |
|---|---|---|
| Control | 5.62[d] | 110.40[b] |
| Full IF | 7.47[a] | 101.40[b] |
| Full CC | 5.64[d] | 110.10[b] |
| Full EMTC | 6.44[c] | 106.00[b] |
| ¼ EMTC + ¾ IF | 7.28[ab] | 117.10[ab] |
| ½ EMTC + ½ IF | 6.87[abc] | 113.00[b] |
| ¾ EMTC + ¼ IF | 6.87[abc] | 132.80[a] |
| ¼ CC + ¾ IF | 6.491[c] | 97.50[b] |
| ½ CC + ½ IF | 6.67[bc] | 107.10[b] |
| ¾ CC + ¼ IF | 6.44[c] | 112.80[ab] |
| LSD (5%) | 0.68 | 18.66 |
| Varieties | | |
| Bishola | 7.26[a] | 116.23[a] |
| Fetane | 5.90[b] | 105.44[b] |
| LSD (5%) | 0.31 | 8.35 |
| CV (%) | 8.9 | 14.4 |

*Means followed by the same letter within the same column are not significantly different at 5% level of significance.*

*Where: IF= inorganic fertilizer, CC= conventional compost and EMTC= effective microorganism treated compost*

### 4.3.3 Pulp weight per fruit

A significant ($p<0.05$) effect of variety and fertilizer were observed for the pulp weight per fruit. However, their interaction showed no significant effect (Table 9 and Appendix Table 5). From all fertilizer treatments, ¾ EMTC plus ¼ gave the highest (132.8 g/fruit) pulp weight per fruit followed by ¼ EMTC plus ¾ IF and ¾ CC plus ¼ IF that is 117.1 and 112.8 g/fruit respectively. The lowest (97.5 g/fruit) pulp weight was recorded from ¼ CC plus ¾ IF. In the contrary to this result Salam (2010) reported that tomato pulp weight greatly is affected by NPK fertilizer and gave higher pulp weight on treatments which were amended with full dose of NPK fertilizer than the lesser. Regarding the varieties, Bishola gave the highest (116.23g) pulp weight per fruit. The difference in pulp weight between the varieties might be because of their difference in fruit size.

### 4.3.4 Fruit pericarp thickness and juice volume

A very highly significant ($p<0.001$) effect of varieties were observed for fruit pericarp thickness and Juice volume. Effect of fertilizer and interaction effect of fertilizer and variety were non-significant (Table 10 and Appendix Table 4 and 5). The highest value of fruit pericarp thickness and Juice volume was recorded for Bishola 0.654 mm and 91.9 ml respectively. However, the lowest value of fruit pericarp thickness and juice volume were recorded from Fetane, 0.598 and 72.6 ml respectively. This result agrees with Meseret (2010) in that Bishola recorded the highest juice volume.

### 4.3.5 Number of seeds per fruit

A very highly significant ($p<0.001$) effect of varieties was observed on the seed number per fruits (Table 10 and Appendix Table 3). The effect of fertilizer and their interaction with variety shows no significance effect on seed number per fruit. The maximum (224.6) number of seeds per fruit was obtained from Bishola, while the lowest (190.8) seed number per fruit was recorded from Fetane variety. The highest number of seeds for Bishola variety could be due to its bigger fruit size. This result is in accordance with Kumar (2007) who reported that number of tomato seeds per fruit differed significantly due to varieties.

Table 10. Effect of variety on fruit pericarp thickness, seed number, juice volume and Titratable acidity of tomato in Jimma

| Varieties | Fruit pericarp thickness (mm) | Seed number | Juice volume (ml) | TTA (%) |
|---|---|---|---|---|
| Bishola | $0.65^{a}$ | $224.60^{a}$ | 91.90a | $0.490^{a}$ |
| Fetane | $0.59^{b}$ | $190.80^{b}$ | $72.60^{b}$ | $0.354^{b}$ |
| LSD (5%) | 0.0311 | 12.31 | 9.56 | 0.0587 |
| CV (%) | 9.4 | 11.3 | 22.2 | 26.6 |

*Means followed by the same letter within the same column are not significantly different at 5% level of significance.*

### 4.3.6 Titratable acidity (% citric acid)

The analysis of variance for the effect of variety showed very highly significant ($p<0.001$) difference on Titratable acidity (Table 10 and Appendix Table 5). The highest 0.49% and significantly different Titratable acidity was recorded from Bishola. On the other hand, the lowest Titratable acidity was recorded from Fetane. This variation could be due to variability in fruit weight. The present result is in agreement with the finding of Tittonell *et al.* (2001) who reported that large sized tomato fruit had higher acidity. The present finding is also in conformity with that of Meseret (2010) who observed a significant variation in the Titratable acidity of tomato varieties in that the highest percentage was recorded for Bishola.

## 4.4 Soil Parameter

Soil Analysis from the experimental field revealed that soil chemical properties such as Soil pH, Organic Carbon (OC), organic matter (OM) and Cation Exchange Capacity (CEC) of the soil showed significant variation (Table 12 and Appendix Table 6). Generally, except the available phosphorus all the tested soil parameters show an increase from the initial soil test but not significantly (Appendix Table 8). The soil microbiological analysis for bacteria and fungi colony count showed significant variation (Table 13 and Appendix Table 7).

### 4.4.1 Soil pH

The analysis of variance for the effect of variety showed a highly significant ($p<0.01$) difference on soil pH (Table 11 and Appendix Table 6). However, the effect of fertilizer and its interaction with variety on soil pH showed no significance ($p \geq 0.05$) differences. The final soil test also shows a slight increase in soil pH from the initial (5.93 to 6.09) (Appendix Table 8). The highest (6.16) soil pH was recorded for Bishola variety.

Table 11 Effect of varieties on soil pH

| **Varieties** | Soil pH |
|---|---|
| Bishola | 6.161[a] |
| Fetane | 6.019[b] |
| LSD (5%) | 0.08 |
| CV (%) | 2.6 |

*Means followed by the same letter within the same column are not significantly different at 5% level of significance.*

### 4.4.2 Cation Exchange Capacity

The effect of fertilizer on CEC shows significant ($P \geq 0.05$) difference (Table 12 and Appendix Table 6). When comparing the pre-planting and after harvest soil tests the soil Cation Exchange Capacity shows an increase from 14.66 to 17.52 (Appendix Table 8). Among the different fertilizers, more CEC was recorded from EMTC alone (19.99) followed by ¾ EMTC plus ¼ IF (19.63), full CC (18.22) and ¾ CC plus ¼ IF (17.33) and the least was recorded from the control (16.33). Variety and the interaction effect did not show significant difference. The CEC strongly influences soil fertility. A higher CEC means that more cations, including plant nutrients, can be loosely stored in a plant available form, giving the plant a greater pool of nutrients to draw from. The CEC soil property allows a reservoir of nutrients to be stored then released to plant roots. This continuous replenishment of nutrients in soil water is very important for several nutrients, including potassium. A high CEC also means that fewer cations will be lost through leaching out of the root zone.

Table 12. Effect of fertilizer on soil Cation exchange capacity (CEC), Organic carbon and organic matter

| Fertilizer | Cation Exchange Capacity (meq/100/gm) | Organic carbon (%) | Organic matter (%) |
|---|---|---|---|
| Control | 16.33$^{c}$ | 2.27$^{e}$ | 4.17$^{c}$ |
| Full IF | 17.20$^{bc}$ | 2.57$^{d}$ | 4.53$^{bc}$ |
| Full CC | 18.22$^{abc}$ | 2.78$^{bc}$ | 4.41$^{bc}$ |
| Full EMTC | 19.99$^{a}$ | 3.08$^{a}$ | 5.13$^{a}$ |
| ¼ EMTC + ¾ IF | 15.75$^{c}$ | 2.64$^{cd}$ | 4.58$^{bc}$ |
| ½ EMTC + ½ IF | 16.98$^{c}$ | 2.54$^{d}$ | 4.60$^{bc}$ |
| ¾ EMTC + ¼ IF | 19.63$^{ab}$ | 2.85$^{b}$ | 4.71$^{ab}$ |
| ¼ CC + ¾ IF | 17.00$^{c}$ | 2.56$^{d}$ | 4.53$^{bc}$ |
| ½ CC + ½ IF | 16.80$^{c}$ | 2.60$^{d}$ | 4.48$^{bc}$ |
| ¾ CC + ¼ IF | 17.33$^{bc}$ | 2.56$^{d}$ | 4.44$^{bc}$ |
| CV (%) | 12.6 | 5.3 | 8 |
| LSD | 2.577 | 0.165 | 0.427 |

*Means followed by the same letter within the same column are not significantly different at 5% level of significance.*

*Where: IF= inorganic fertilizer, CC= conventional compost and EMTC= effective microorganism treated compost*

### 4.4.3 Organic Carbon (%)

Fertilizer effect showed a very highly significant ($p<0.001$) difference on organic carbon (Table 12). However, variety and their interaction with fertilizer showed no significant difference. All fertilized plots showed significant difference over the control treatment. Higher organic carbon content of soil recorded from full EMTC (3.083%) followed by ¾ EMTC plus ¼ IF (2.85%) and full CC (2.785%). Least organic carbon content was recorded from the control plot (2.273%). Generally, plots having more amount of organic fertilizer show higher percentage of organic carbon and from all the treatments, those having more proportion of EMTC gave higher soil organic carbon over the other. This result is in line with the Reza and Jafar (2007) report who reported that addition of organic fertilizer resulted in increased total OC. Maheswarappa *et al.* (1997) observed that, organic carbon content was increased to a greater extent with FYM and vermicompost application other sources. Javariaa & Khana (2011) also reported that an increase in organic C is obvious in soils receiving combined application of organic manures and inorganic fertilizers compared to soils receiving inorganic fertilizers only.

### 4.4.4 Soil Organic Matter (OM)

The effect of fertilizer showed a significant ($p<0.05$) differences on soil organic matter content (Table 12 and Appendix Table 6). However, interaction effect of different Fertilizer treatments and varieties on organic matter showed no significance ($p\geq0.05$) differences. Higher organic matter content of soil recorded from full EMTC (3.083%) followed by ¾ EMTC plus ¼ IF (5.130) and full CC (4.708). Least organic matter content was recorded from the control plot (4.177). All other treatments gave statistically similar results but greater than that of the control and the initial value. From all the treatments, those having more proportion of EMTC gave higher soil organic matter. Generally, all fertilized plots shows significant difference over the control treatment. This result is in line with the result of Reza and Jafar (2007) who reported that addition of organic fertilizer resulted in increased total organic matter than that of inorganic fertilizer.

### 4.4.5 Soil biological properties

The analysis of variance for the effect of fertilizer shows highly significant ($p<0.001$) difference on total microbial count per gram of soil (Table 13 and Appendix Table 7).

However, interaction effect of fertilizer with varieties showed no significance ($p \geq 0.05$) differences. All the fertilized plots significantly increased the total soil bacteria and fungal colonies over the control (no fertilizer applied).

The highest and significantly different number of total bacterial and fungi colonies was found from full EMTC (8.137 and 6.739 CFU $g^{-1}$ soil (log 10)) respectively and the least total bacterial and fungi colonies (7.562 and 6.154 CFU $g^{-1}$ soil (log 10)) is recorded from the control treatment. More number of total bacterial and fungi colonies was found for more proportion of EMTC and CC. The increase in total bacterial and fungi colonies under high EMTC and CC proportion may be due to the increasing microbial content of soil attributed from the organic fertilizer and the superiority of the EMTC treatments over the other could be due to its active microbial composition.  In line with this Chithesh (2005) observed that the total count for bacteria, fungi and actinomycetes was significantly higher in all the treatments that received organic fertilizers. In addition, plots that received their nutrients through 100 % organic recorded the highest count for bacteria, fungi and actinomycetes. The lowest count for bacteria, fungi and actinomycetes was found to be in the treatment wherein only 100 % inorganic fertilizers were applied.

Table 13. Effect of fertilizer on soil bacteria and fungi population

| Fertilizer | Bacteria (CFU $g^{-1}$ soil log 10) | Fungi (CFU $g^{-1}$ soil log 10) |
|---|---|---|
| Control | $7.56^{g}$ | $6.15^{h}$ |
| Full IF | $7.67^{f}$ | $6.30^{g}$ |
| Full CC | $8.07^{b}$ | $6.53^{c}$ |
| Full EMTC | $8.14^{a}$ | $6.74^{a}$ |
| ¼ EMTC + ¾ IF | $7.89^{d}$ | $6.43^{e}$ |
| ½ EMTC + ½ IF | $8.01^{c}$ | $6.47^{de}$ |
| ¾ EMTC + ¼ IF | $8.09^{b}$ | $6.57^{b}$ |
| ¼ CC + ¾ IF | $7.67^{f}$ | $6.50^{cd}$ |
| ½ CC + ½ IF | $7.78^{e}$ | $6.38^{f}$ |
| ¾ CC + ¼ IF | $8.04^{bc}$ | $6.49^{cd}$ |
| CV (%) | 0.5 | 0.6 |
| LSD | 0.045 | 0.042 |

*Means followed by the same letter within the same column are not significantly different at 5% level of significance.*

*Where: IF= inorganic fertilizer, CC= conventional compost, EMTC= effective microorganism treated compost and CFU= colony forming unit*

# 5 SUMMARY AND CONCLUSION

Tomato is one of the most widely grown vegetables in the world. The popularity of tomato among consumers has made it an important source of lycopene and vitamin C, A and E in diets. As a processing crop, it ranks first among all vegetables grown throughout the world. It is one of the most popular salad vegetables. It is widely employed in cannery and made into soups, conserves, pickles, ketchup, sauces, juices etc. China is the world biggest tomato producer followed by United State and Turkey, from Africa Egypt and Nigeria are the major tomato producers

Increasing production of the crop has a great role to strength the growing tomato production industries in the country. However, the production and productivity of the crop in the country is influenced by different factors among many contributing factors, lack of optimum fertilizer use among tomato growers is a felt problem. In order to improve the yield and quality of tomato, there should be the technologies which will eventually fulfill the grower as well as consumer's need. Studies on management practices, particularly on the management of fertilizer specially treating compost by effective microorganism would help increasing yield of tomato. EM increases yield and enhances quality through improving soil fertility and reduce costs, make use of the chemical fertilizer more effective and reduce losses

Keeping this fact in view this research was carried out to determine the comparative benefits of using organic (with and with out effective microorganism treatment) and inorganic fertilizers in combination or alone in respect of yield and quality of tomato (*Lycopersicon esculentum Mill*) at Jimma. Two tomato varieties namely Bishola and Fetane were grown on plot incorporated with ten fertilizer combinations (Control (with no fertilizer), inorganic fertilizer (IF) alone, conventional compost (CC) alone, EM treated compost (EMTC) alone, ¼ EMTC + ¾ IF, ½ EMTC + ½ IF, ¾EMTC+ ¼ IF, ¼ CC + ¾ IF, ½ CC + ½IF and ¾ CC + ¼ IF) during the year 2010/11 under irrigation using Randomized Complete Block Design (RCBD) replicated three times. Fertilizer were applied at the rate of 200kg/ha for DAP, 150kg/ha for Urea and 10t/ha for both EM treated and untreated compost.

In this study, effects of co-application of EM treated and untreated compost with inorganic fertilizer on growth, yield, and quality of tomatoes and the impact of integrated application of EM treated and untreated compost with inorganic fertilizers on soil characteristics was investigated. Generally, the result showed a significant response of integrated application of organic fertilizer and inorganic fertilizer significantly increased growth, yield and yield components of tomato varieties.

The growth parameters like plant height, primary branch plant$^{-1}$, days to 50% flowering, flowers per cluster, days to fruit maturity, duration and number of harvest were significantly influenced by different combination of fertilizers and variety. Similarly, among the yield contributing characters number of flower cluster plant$^{-1}$, fruit cluster$^{-1}$, fruit length, fruit diameter, number of fruit$^{-1}$, average fruit weight, fruit yield plant$^{-1}$, total fruit yield and marketable yield of tomato under the study also varied significantly. Regarding the quality parameters, Bishola performed best over Fetane.

The highest and significantly different marketable fruit yield (44.01 t/ha), fruit yield per plant (1026.10 g/plant), total fruit yield per hectare (47.92 t/ha) and fruit number (14.53) was recorded from Fetane that received ¼ EMTC plus ¾ IF. Marketable fruit yield was strongly and positively correlated with total yield per hectare (r=0.99***), total yield per plant (r=0.97***), number of fruits per plant (r=0.96$^{***}$), number of fruits per cluster (r=0.74***), primary branches per plant (r=0.95***) and fruit length (r=0.83$^{***}$) (Appendix Table 9).

Fetane variety that received ¼ EMTC + ¾ IF performed best almost for all yield contributing characteristics. Therefore, it can be suggested for obtaining higher yield of tomato fruits, which may help to reduce the use of inorganic fertilizers.

The highest organic carbon, CEC, organic matter, bacteria and fungi colony were recorded from full dose of EMTC followed by ¾ EMTC + ¼ IF. It can be stated that application of organic compost specially treated by EM can significantly increase the soil nutrient content. Based on these results it can be concluded that EM is extremely important combination for sustainable agriculture. It improves the soil organic matter, adds soil nutrients, improves soil physical and inorganic properties and stimulates soil biological and enzyme activities. It has very valuable effect on tomato growth, yield and quality parameters and most importantly, it is environmentally friendly.

However, before making any final recommendation the effect of these treatments should be seen on subsequent crops and at various soil and agro climatic conditions to generate more reliable information, the local community should be sensitized on the use of EM and cost benefit analysis should be done.

# 6 REFERENCE

Adugna Gessesse Teka, 2009. Analysis of fruit and vegetable market chains in Alamata, southern zone of tigray: the case of Onion, tomato and papaya. A Thesis Submitted to the Department of Agricultural Economics, School of Graduate Studies, Haramaya University, Ethiopia.

AGRISNET (Agriculture Information System Network), 2010. Tomato. Department of Agriculture, Sikkim, India. (http://www.sikkimagrisnet.org/General/en/Tomato.aspx)

Andersen, P. C., Rhoads, F. M., Olson, S. M. and Hill, K. D. 1999. Carbon and nitrogen budgets in spring and fall tomato crops. *HortScience* **34**: 648–652.

Anonymous, 2011. Tomato nutrition facts and health benefits. In: Nutrition Facts in the Food. http://www.nutrition-and-you.com

APNAN (Asia-Pacific Natural Agriculture Network), 1995. EM Application Manual for APNAN Countries, M. Shintani (Ed.) 1st Ed. Bangkok, Thailand.

AVRDC (Asian Vegetable Research and Development Center), 1997. Training report of the fifth regional training program in vegetable production and research. p. 118-126, 169-184. Kasetsart University Bangkok, Thailand.

Balibrea, M.E., B.K. Dazie and D.J. Cleland, 1997. Reducing gas exchange of fruits surface coatings. Post harvest handling of tomato fruit.

Black, C.A.1965. Methods of soil analysis. Part I, American society of Agronomy. Madison, Wisconsin, USA.1572p.

BPEDORS, 2000. Physical and socio economical profile of 180 district of Oromia region pp. 248-251 Bureau of Planning and Economic Development of Oromia Regional State (BPEDORS), physical planning development. Addis Ababa, Ethiopia.

Chamberlain, T.P. and M.J. Daly, 2001. Innovative use and adaptation of a microbial technology (EM) for large scale vegetable, Arable and stock production on an organic farm in Canterbury, New Zealand

Chand, S., M. Anwar, & D.D. Patra. 2006. Influence of long-term application of organic and inorganic fertilizer to build up soil fertility and nutrient uptake in mint mustard cropping sequence. Communications in Soil Science and Plant Analysis, **37**: 63-76.

Chanda Goutam Kumar, Goutam Bhunia and Susanta Kumar Chakraborty 2011. The effect of vermicompost and other fertilizers on cultivation of tomato plants. *Journal of Horticulture and Forestry* **3**(**2**):42-45.

Chapman, H.D.1965.Cation exchange capacity. In: C.A. Black, L.E. Ensiminger and F.E. Clark (eds). Methods of soil analysis Agronomy.**9**:891-901.Am.Soc.Agro., Inc., Madison,Wisconsin.

Ching Fang, H. and Kvonon, H., 1994, Effect of organic manures on the growth and yield of sweet pepper. *Bull. Juching District Agric. Improv. Stat.*, **42** : 1-10.

Chithesh, C. 2005. Studies on use of organics in tomato (*Lycopersicon esculentum* Mill) production. M.Sc. Thesis, Kittur Rani Channamma College of Horticulture, Arbhavi, Belgaum, Karnataka.

Chrispaul Muthaura, M. David Musyimi, A. Ogur Joseph and V. Okello Samuel. 2010. Effective Microorganisms and Their Influence on Growth and Yield of Pigweed. ARPN (Asian Research Publishing Network) *Journal of Agricultural and Biological Science*. **5** (**1**). www.arpnjournals.com/jabs/research_papers/rp.../jabs_0110_168.pdf

Correa Margarita. 2001. The impact of effective microorganisms (EM) in various farming Systems. Auroville, India.

Costa J.M. and E. Heuvelink 2004. Tomatoes In: Ep Heuvelink (eds). Crop production science in horticulture series. Wageningen University, Netherlands.

Daly, M.J. Stewart, D.P.C. 1999. Influence of "Effective Microorganisms" (EM) on vegetable production and carbon mineralization a preliminary investigation. *Journal of Sustainable Agriculture* **14** (**2**).

Daly, Mike. 2004. An Overview of EM technology in New Zealand. Proceedings of the EM European Conference. Cultural centre de Meervaart Amsterdam, 18-20 September 2004.

Daniel Mekonnen, 2006. Effects of integrated nutrient management on agronomic performance of potato (*Solanum tuberosum*. L. ) and fertility of nitosol at Bako. A MSc. Thesis presented to the School of Graduate Studies of Alemaya University, Ethiopia.

David Gentilcore, 2010. A History of the Tomato in Italy Pomodoro. Columbia University Press. pp 25-31 (http://cup.columbia.edu/book/978-0-231-15206-8/pomodoro)

Dewis, J. and P. Freitas, 1970. Physical and Chemical Methods of Soil and Water Analysis. FAO Bull. No.10, Rome. 271p.

Dinesh, R., Dubey, R.P., Ganeshamurthi, A.N. and Prasad, G.S. 2000. Organic manuring in rice-based cropping systems: Effect on soil microbial biomass and selected enzyme activities. *Current Sci.*, 79(12):35.

Diver, S. (2005), *Organic Tomato Production*; http://attra.ncat.org/attra-pub/PDF/tomato.pdf

EMRO (Effective Microorganisms Research Organization). 2011. (http://emrojapan.com )

FAO, 2000. Fertilizers and Their Use. A handbook guide for Extension Officers. 4th Ed. Food and Agriculture Organization of United Nations and International Fertilizer Industry Association. Rome, Italy.

FAOSTAT. 2011. Statistical Database of the Food and Agriculture of the United Nations. FAO, Rome, Italy. (http://faostat.fao.org/site/612/default.aspx#ancor)

Getachew Gebru, Beyene Chichaibelu and J.D. Reed, 1989. Effects of processing methods on chemical composition and in vivo digestibility of coffee pulp in Ethiopia. p. 56. Proceedings of Utilization of research results on forage and agricultural by-product materials as animal feed resources in Africa. Addis Ababa, Ethiopia.

Gossavi, D. 2005. Effect of organic production on yield and quality of RTH-2. M.Sc (Agri.) Thesis, Mahatma Phule Krishi Vidyapeeth, Rahuri (MS).

Gunadi, B., Blount, C. and Edwards, C.A. 1999. The growth and fecundity of *Eisenia fetida* (Saviguy) in cattle solids pre composted for different periods. *Pedobiologia*, 46(1):15-33.

Hegde D.M. 1997. Nutrient Requirements of Solanaceous Vegetable Crops. All India Coordinated Safflower Improvement Project. Solapur, Maharashtra, India

Herrero, E. V., Mitchell, J. P., Lanini, W. T., Temple, S. R., Miyao, E. M., Morse, R. D. and Campiglia, E. 2001. Use of cover crop mulches in a no-till furrow-irrigated processing tomato production system. *HortTechnology* **11**: 43–48.

Higa, T. 1996. Effective microorganisms - Their role in Kyusei Nature Farming. In: J.F. Parr, *et al.* (eds.), Proceedings of the 3rd International Nature Farming Conference. USDA; Washington, 20-23.

Higa T. and J.F. Parr (1994). Beneficial and effective microorganisms for a sustainable agriculture and environment. International Nature Farming Research Center, Atami, Japan.

Higa, T. and G.N. Wididana 199l. Changes In the soil microflora Induced by effective microorganisms. p.153-162. In J.F. Parr, S.B. Hornick, and C.E. Whitman (ed.) Proceedings of the First International Conference on Kyusei Nature Farming. U.S. Department of Agriculture, Washington, D.C., USA.

Hussain, T., T. Javaid, J.F. Parr, G. Jilani and M.A. Haq, 1999. Rice and wheat Production in Pakistan with Effective Microorganisms. *A. J.Alt. Agri.*, **14**: 30-6.

Jagadeesha V., 2008. Effect of Organic Manures and Biofertilizers on Growth, Seed Yield and Quality in Tomato (*Lycopersicon esculentum* Mill.). A Thesis submitted to the University of Agricultural Sciences, Dharwad, India.

Javaria, Sadaf and Khan, M. Qasim, (2011). Impact of integrated nutrient management on tomato yield quality and soil environment, *Journal of Plant Nutrition,* **34(1):**140-149

Jen-Hshuan Chen, 2007, The Combined Use of Chemical and Organic Fertilizers and/or Biofertilizer for Crop Growth and soil fertility. FFTC (Food & Fertilizer Technology Center) Taiwan, (http://www.agnet.org/library/tb/174/)

Kapoor K.K. and Shashi Paroda, 2007. Experimental Soil Microbiology 1st Ed. pp 1-12. Department of microbiology, CCS Haryana Agricultural University, India.

Khaliq, A., M. Kaleem & T. Hussain, 2006. Effects of integrated use of organic and inorganic nutrient sources with effective microorganisms (EM) on seed cotton yield in Pakistan. *Bioresource Technology* **97:**967-972.

Kumar Sanjeev, 2007. Studies on hybrid seed production in tomato (*Licopersicon esculentum* Mill.). A Thesis submitted to the University of Agricultural Sciences, Dharwad

Krishina, H.C. and Krishnappa, K.S. 2001. Growth and yield of tomato cv. Avenash-2 in relation to inorganic fertilizers and organic manures. *South Indian Hort.,* 50(4-6):335-341.

Lemma, D., 2002. Tomato Research experience and production prospects. Research report No 43 Ethiopian Agricultural Research Organization, Ethiopia.

Lemma D, Z. Yayeh and E. Helath, 2003. Agronomic studies on Tomato and Capsicum. Pp.153. In: Helath E. and Lemma D, (Eds). Horticultural Research and Development in Ethiopia. Proceedings of the second Horticultural work shop of Ethiopia, 1-3 December, 1992. Addis Ababa, Ethiopia

Li W and Ni Y (1995). Research and application of EM (Effective Microorganisms). *Chin. J. Ecol.* 14: 58 - 62.

Maheshwarappa, H. P., Nanjappa and M. R. Hegde, 1997, Influence of organic manures on yield of arrowroot, soil physico-chemical and biological properties when grown as a intercrop in coconut garden. *Ann. Agric. Res.*, **20**(3) : 318-323.

Malik, A. A., M. A.1 Chattoo, G. Sheemar, and R. Rashid, 2011. Growth, yield and fruit quality of sweet pepper (*Capsicum annuum* L.) as affected by integration of inorganic fertilizers and organic manures (FYM) Journal of Agricultural Technology Vol. 7(4):1037-1048

MARD (Ministry of Animal and Plant Health Regulatory Directorate), 2009. Crop variety register issue No. 12 Addis Ababa Ethiopia.

Maria Jose Diez and Fernando Nuez, 2008. Tomato: In: Jaim Prohems & Fernando Nuez (eds) Handbook of plant breeding, Vegetable I & II pp 249-323. Springer Publisher New York.

Meherunnessa, N.M. Talukder & H.M. Zakir, 2011. Influence of compost and fertilizers on growth, Yield and some Biochemical composition of summer tomato. Bangladesh Research Publication Journal **5**(**4**):344-350.

Menberu Kitila, 2011. Effect of intra-row spacing and variety on fruit yield and quality of tomato under Jimma, condition. A MSc. Thesis presented to the School of Graduate Studies of Jimma University Collage of Agriculture and Veterinary Medicine, Ethiopia.

Meseret Degefa, 2010. Evaluation of tomato varieties for fruit yield, quality and shelf life. A MSc. Thesis presented to the School of Graduate Studies of Jimma University Collage of Agriculture and Veterinary Medicine, Ethiopia.

Misra, R.V., Roy, R.N. and Hiraoka, H. 2003. On-farm composting methods. FAO, Rome.

MoARD (Ministry of Agriculture and Rural Development), 2005. Crop Variety Register: Animal and Plant Health Regulatory Directorate. Issue No. 12. Addis Ababa, Ethiopia. P. 145.

MoARD, 2009. Rural Capacity Building Project. Course for Training of trainers on improved horticultural crop technologies. Addis Ababa, Ethiopia.

Moigradean Diana, A. Lazureanu, I. Gogoasa, Mariana-Atena Poiana, Monica Harmanescu and I. Gergen, 2007. Influence of NPK Fertilization on Nutritional Quality of Tomatoes. Buletin USAMV

Muriithi, L..M and J.W. Irungu, 2004. Effects of integrated use of inorganic fertilizer and organic manures on bacterial wilt incidence and tuber yield in potato production systems on hill slopes of central Kenya. *J. Mountain Sci.* (**1**): 81-88.

Nandani, T., 2006. Effect of organic, conventional and integrated form of nutrient management systems on growth, yield and quality of tomato (*Lycopersicon esculentum* Mill.). M.Sc. Thesis, Kittur Rani Channamma College of Horticulture, Arbhavi, Belgaum, Karnataka.

Nanthakumar, B. and Veerargavathatham, D. 1999. Effect of integrated nutrient management on keeping quality of brinjal (*Solanum melongena* L.). *South Indian Hort.*, **47**(**1-6**):81-85.

Ncube Lindani, 2008. Thesis: Evaluation Of Effective Micro-Organisms (EM) On Soil Chemical Properties And Yield Of Selected Vegetables In The Eastern Cape, South Africa. (http://ufh.netd.ac.za/jspui/bitstream/10353/86/1/NcubeL%20thesis.pdf).

Ncube Lindani, Pearson Nyari S. Mnkeni and Marc Olivier Brutsch, 2011. Agronomic suitability of effective micro-organisms for tomato production. *African Journal of Agricultural Research* **6**(**3**): 650-654.

Nileema S. Gore and M. N. Sreenivasa, 2011. Influence of liquid organic manures on growth, nutrient content and yield of tomato (*Lycopersiconesculentum* Mill.) in the sterilized soil. *Karnataka J. Agric. Sci.*, **24** (**2**): 153-157

Ogbomo K.E. Law and R.K.A. Egharevba, 2009. Effects of Planting Density and NPK Fertilizer Application on Yield and Yield Components of Tomato (*Lycospersicon esculentum* Mill) in Forest Location. *World Journal of Agricultural Sciences* **5** (**2**): 152-158

Ogbomo K.E. Law, 2011. Comparison of growth, yield performance and profitability of tomato under different fertilizer types in humid forest ultisols. *International Research Journal of Agricultural Science and Soil Science* **1**(**8**):332-338 (http://www.interesjournals.org/IRJAS)

Pandey, A., C. R. Soccol, P. Nigam, D. Brand, R. Mohan and S. Roussos, 2000. Biotechnological potential of coffee pulp and coffee husk for bioprocesses. *Journal of Biochemical Engineering.* **6:**153-162

Patil, M.B., Ghadge, P.M. and Mohammed, R.G. 2004. Effect of organic and inorganic fertilizers on growth, yield and quality of tomato. *J. Maharashtra Agric. Univ.*, 29(2):124-127.

Patil, M.P., 1995, Integrated nutrient management in commercial vegetables. M. Sc. (Agri) Thesis, Univ. Agric. Sci., Dharwad, Karnataka, India.

Paulraj, C., Raniperumal and Balasundaram, C. S., 1982, Effect of different sources of N on the protein content and yield of tomato fruit. *Madras Agril. J*., 69 (9) : 621-622.

Rafi, M., Narwadkar, P.R., Prabu, T., and Sajindranath, A.K. 2002. Effect of organic and inorganic fertilizers on growth and yield of tomato (*Lycopersicoon esculentum* Mill.). *South Indian Hort.*, 50(4-6):522-526.

Reddy, C.S., Narayanamma, M., Chiranjeevi, CH., and Reddy, I.P. 2002. Effect of nutrient sources on the fruit yield of tomato (*Lycopersicon esculentum* Mill.). *Veg. Sci.*, 29(2):193-194.

Reza, M. T., and K. Jafar. 2007. Influence of organic and chemical fertilizers on growth and yield of tomato (*Lycopersicon esculentum* L.) and soil chemical properties. Annual Report. Shahid Beheshti University. Tehran, Iran.

Robert Gourlay. 2009. Effective Microorganisms (EM): The Mother Culture for Biological Farming. ERIC (Environmental Research and Information Consortium). (http://www.eric.com.au/html/microbes_culture.php )

Rowell, D.L.1994.Soil science: Methods and applications. Addison Wesley Longman Singapore publishers. England, UK.350pp.

Roy, R. N. 1986. FAO Fertilizer Program with Special Reference to Integrated Plant Nutrition System. Fertilizer in Agricultural Development. New Delhi, India.

Salam M.A., M.A. Siddique, M.A. Rahim, M. A. Rahman and M.G. Saha, 2010. Quality of tomato *(Lycopersicon esculentum* Mill.) as influenced by boron and zinc under different levels of NPK fertilizers. Bangladesh J. Agril. Res. 35(3) : 475-488.

Sangakkara, U.R. 1990. Research on the Technology of Effective Microorganisms in Sri Lanka. Department of Crop Science University of Peradeniya, Peradenlya, Sri Lanka

Sanjay Arora, Balanced Nutrition for Sustainable Crop Production. Department of Soils, Punjab Agricultural University Ludhiana. http://www.krishiworld.com

SAS Institute Inc. 2008. Statistical analysis Software version 9.2, Cary, NC: SAS Institute Inc. USA.

Seliga, J. P. and Shattuck, V. I. 1995. Crop rotation affects the yield and nitrogen fertilization response in processing tomatoes. *Sci. Hortic*. **64**: 159–166.

Sendur, K. S., S. Natarajan, and S. Thamburaj, 1998, Effect of organic and inorganic fertilizers on growth, yield and quality of tomato. *South Indian Hortic*., 46 (3 and 4) : 203-205.

Shalini, S.B., H.T. Channal, N.S.Hebsur, P.R, Dharmatti, and P.A. Sarangamath, 2002. Effect of integrated nitrogen management on nutrient uptake in knolkhol, yield and nutrient availability in the soil. *J. Karanataka Agri. Sci.***15** (**1**): 43-46.

Shamshad Hussain Shah, M. Farrukh Saleem and M. Shahid, 2001. Effect of Different Fertilizers and Effective Microorganisms on Growth, Yield and Quality of Maize. *International Journal of Agriculture & Biology* **3**(**4**). Department of Agronomy, University of Agriculture, Faisalabad, Pakistan.

Shankara Naika, Joep van Lidt de Jeude, Marja de Goffau, Martin Hilmi and Barbara van Dam. 2005 Cultivation of Tomato: Production, Processing and Marketing. $4^{th}$ Ed Agromisa Foundation and CTA, Wageningen, Netherlands.

Sundaram V., A. Udaykumar, and E. Vadivel, 2004. Effective microorganisms on growth and yield of Radish (*Raphanus sativus* L.). Horticulture College and Research Institute, Tamil Nadu Agricultural Univesity, Coimbatore, India.

Sung J. M. and K.H. Lee. 2010. Improvement of Tomato Cultivation by Effective Microorganisms. Department of Biology, Kang Won National University.

Taiwo L. B., Adediran J. A. and Sonubi O. A., 2007. Yield and Quality of Tomato Grown with Organic and Synthetic Fertilizers, *International Journal of Vegetable Science,* **13**:2. Internet documents (http://ijvs.haworthpress.com)

Taylor JH. 1987. Text of lectures delivered at the national workshop on fruit and vegetable seedlings production held at NIHORT 9-13

Tei, F., Benincasa, P. and Guiducci, M. 2002. Critical nitrogen concentration in processing tomato. *Eur. J. Agron.* **18**: 45–55.

Teshome Abdissa, Amanti Chali, Geremew Hawas and Taha Mume. 2010. Effect of seedling management on yield and quality of tomato at Adami Tulu Jiddo Kombolcha District, Central Rift Valley of Ethiopia. *African Journal of Agricultural Research* **5(22)**: 3056-3059

Tisdal, J. M. 1994. Possible role of soil microorganisms in aggregation in soils. In Management of Mycorrhizae in agriculture.

Tittonell P, J. Degrazia, A. Chiesa. 2001. Effect of nitrogen fertilization and plant population during growth on lettuce (*Lactuca sativa* L.) post harvest quality. Proceedings of the Fourth International Conference on Postharvest Science. Acta Hort **553**(**1**):67–68

Tremblay, N., Scharpf, H-C., Weier, U., Laurence, H. and Owen, J. 2001. Nitrogen management in field vegetables: a guide to efficient fertilization. AAFC, Ottawa

WAI (Woljeejii Agro-Industry PLC), 2009. Training Manual on the Utilization of Effective Micro Organisms. Ethiopia.

Walkley, A. and I.A.Black.1934.An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil sci **37**:29-38

Wener Zvi Howard, 2000. Importance of the tomato. Agri-support online agricultural articles http://www.agrisupportonline.com/Articles/importance_of_the_tomato.htm

Wintgon, J.N, 2004. Coffee: Growing, Processing, Sustainable Production. A Guide book for Growers, Processors, Traders, and Researchers 2nd revised edition

Woodward Dan, 2003. Soil and sustainability: Effective microorganisms as Regenerative Systems in Earth Healing, internet document, http://www.livingsoil.co.uk/learning/soilsustain.htm

Yamada, K. and H. Xu, 2000. Properties and applications of an organic fertilizer inoculated with Effective Microorganisms. In: Xu, H., J.F. Parr & H. Umemura (eds). Nature Farming and Microbial Applications, New York, pp: 255-268.

Zarb, J, C. Leifert and A. Litterick 2001. Opportunities and Challenges for the Use of Microbial Inoculants in Agriculture.

# 7 APPENDICES

Appendix Table 1. Means squares for plant height, number of primary branches, days to 50 % flowering, flower clusters per plant and flowers per cluster of tomato

| Source of variation | d.f. | Mean squares | | | | |
|---|---|---|---|---|---|---|
| | | Plant Height (cm) | Number of Primary branch (No) fruit$^{-1}$ | Days to 50% flowering (Day) | Flower cluster (No) plant$^{-1}$ | Flower (No) cluster$^{-1}$ |
| Block | 2 | 6.171 | 0.098 | 0.350 | 0.017 | 0.010 |
| Fertilizer | 9 | 227.780*** | 3.115*** | 68.639*** | 32.705 *** | 3.637*** |
| Variety | 1 | 666.667*** | 3.408*** | 54.150*** | 14.017*** | 9.295*** |
| Ferti*Variety | 9 | 4.200** | 0.140*** | 3.113*** | 0.350*** | 0.171*** |
| Error | 38 | 1.073 | 0.007 | 0.227 | 0.017 | 0.012 |

*Ns= Non-significant, *, ** and *** = significant difference at 5%, 1% and 0.1% probability levels, respectively*

Appendix Table 2. Means squares for days to fruit maturity, fruits per cluster, fruit set percentage, harvesting duration and number of harvest of tomato

| Source of variation | d.f. | Mean squares | | | | |
|---|---|---|---|---|---|---|
| | | Days to fruit Maturity (Day) | Fruit per cluster | Fruit set percentage | Harvesting duration | Number of Harvest |
| Block | 2 | 9.317 | 0.004 | 0.694 | 2.217 | 0.35 |
| Fertilizer | 9 | 107.00*** | 8.141*** | 1137.8*** | 40*** | 4.141*** |
| Variety | 1 | 117.600*** | 0.831*** | 1484.86*** | 72.6*** | 13.07*** |
| Ferti*Variety | 9 | 8.674** | 0.579*** | 141.318*** | 3.86$^{ns}$ | 0.4 $^{ns}$ |
| Error | 38 | 2.211 | 0.025 | 8.959 | 4.34 | 0.736 |

*Ns= Non-significant, *, ** and *** = significant difference at 5%, 1% and 0.1% probability levels, respectively*

Appendix Table 3. Means squares for fruit length, fruit diameter, fruit shape index, fruit pericarp thickness and number of seed fruit$^{-1}$ of tomato.

| Source of variation | d.f. | Mean squares | | | | |
|---|---|---|---|---|---|---|
| | | Fruit length (cm) | Fruit Diameter (cm) | Fruit Shape Index | Fruit pericarp thickness (mm) | Seed number (No) fruit$^{-1}$ |
| Block | 2 | 0.0117 | 0.259 | 0.022 | 0.002 | 7035.7 |
| Fertilizer | 9 | 9.499*** | 2.205*** | 0.0392* | 0.003 $^{ns}$ | 977.1$^{ns}$ |
| Variety | 1 | 19.073*** | 27.586*** | 3.1068*** | 0.047*** | 17150*** |
| Ferti*Variety | 9 | 1.066*** | 0.233$^{ns}$ | 0.0699*** | 0.004$^{ns}$ | 617.5$^{ns}$ |
| Error | 38 | 0.150 | 0.344 | 0.014 | 0.003 | 554.6 |

*Ns= Non-significant, *, ** and *** = significant difference at 5%, 1% and 0.1% probability levels, respectively.*

Appendix Table 4. Means squares for seed weight, pulp weight, juice volume, total soluble solid and Titratable acid of tomato.

| Source of variation | d.f. | Mean squares | | | | | |
|---|---|---|---|---|---|---|---|
| | | Seed weight (g) fruit$^{-1}$ | Pulp weight (g) fruit$^{-1}$ | Juice Volume (ml) fruit$^{-1}$ | Pulp to seed ratio | TSS ($^0$Brix) | TA |
| Block | 2 | 0.22385 | 698.1 | 72.2 | 0.0996 | 0.248 | 0.046 |
| Fertilizer | 9 | 0.03722$^{ns}$ | 557.4* | 589$^{ns}$ | 0.03069$^{ns}$ | 0.41$^{ns}$ | 0.014$^{ns}$ |
| Variety | 1 | 0.12119$^{ns}$ | 1744.2* | 5565.8*** | 0.013$^{ns}$ | 0.37$^{ns}$ | 0.28*** |
| Ferti*Variety | 9 | 0.01086$^{ns}$ | 278.1$^{ns}$ | 238.5$^{ns}$ | 0.0152$^{ns}$ | 0.54$^{ns}$ | 0.009$^{ns}$ |
| Error | 38 | 0.0399 | 255 | 334.5 | 0.03052 | 0.28 | 0.013 |

*Ns= Non-significant, *, ** and *** = significant difference at 5%, 1% and 0.1% probability levels, respectively.*

Appendix Table 5. Means squares for fruit number per plant, average fruit weight per plant, average fruit yield per plant, total fruit yield ha$^{-1}$, marketable fruit yield ha$^{-1}$ and unmarketable fruit yield ha$^{-1}$.

| Source of variation | d.f. | Mean squares | | | | | |
|---|---|---|---|---|---|---|---|
| | | fruit number (No) plant$^{-1}$ | Average fruit weight (g) plant$^{-1}$ | Total yield (g) plant$^{-1}$ | Total yield (t) ha$^{-1}$ | Marketable yield (t) ha$^{-1}$ | Unmarketable yield (t) ha$^{-1}$ |
| Block | 2 | 0.0887 | 383.64 | 464.8 | 0.717 | 0.099 | 0.29 |
| Fertilizer | 9 | 14.802*** | 1578.86*** | 173806*** | 354.4*** | 356.42*** | 0.152$^{ns}$ |
| Variety | 1 | 50.784*** | 2036.42** | 232617*** | 512*** | 610.99*** | 4.37*** |
| Ferti*Variety | 9 | 0.815** | 364.55* | 13061*** | 19.58*** | 20.94*** | 0.30$^{ns}$ |
| Error | 38 | 0.1267 | 150.21 | 773.7 | 1.029 | 1.66 | 0.309 |

*Ns= Non-significant, *, ** and *** = significant difference at 5%, 1% and 0.1% probability levels, respectively.*

Appendix Table 6. Mean squares for Soil chemical properties

| Source of variation | d. f. | Mean squares | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | SpH | ppm P | %N | %OC | %OM | K(MEQ/ 100gm) | CEC(meq/ 100/gm) |
| Block | 2 | 0.1213 | 10582 | 0.0471 | 0.0365 | 0.2350 | 0.1533 | 16.08 |
| Fertilizer | 9 | 0.009$^{ns}$ | 1638$^{ns}$ | 0.0008$^{ns}$ | 0.282*** | 0.3613* | 0.1342$^{ns}$ | 11.22* |
| Variety | 1 | 0.301** | 11$^{ns}$ | 0.0005$^{ns}$ | 0.031$^{ns}$ | 0.0859$^{ns}$ | 0.33$^{ns}$ | 1.43 |
| Ferti*Variety | 9 | 0.017$^{ns}$ | 8300$^{ns}$ | 0.0024$^{ns}$ | 0.018$^{ns}$ | 0.1539$^{ns}$ | 0.2086$^{ns}$ | 3.21 |
| Error | 38 | 0.0256 | 3945 | 0.0019 | 0.020 | 0.1333 | 0.1709 | 4.86 |

*Ns= Non-significant, *, ** and *** = significant difference at 5%, 1% and 0.1% probability levels, respectively.*

Appendix Table 7 Mean squares for Soil bacterial and fungi CFU g soil$^{-1}$(log10)

| Source of variation | d.f. | Mean squares | |
|---|---|---|---|
| | | Bacterial CFU g soil$^{-1}$(log10) | Fungal CFU g soil$^{-1}$(log10) |
| Block | 2 | 0.017606 | 0.021624 |
| Fertilizer | 9 | 0.261438*** | 0.150140*** |
| Variety | 1 | 0.000002$^{ns}$ | 0.003687$^{ns}$ |
| Ferti*Variety | 9 | 0.000842$^{ns}$ | 0.000257$^{ns}$ |
| Error | 38 | 0.001460 | 0.001315 |

*Ns= Non-significant, *, ** and *** = significant difference at 5%, 1% and 0.1% probability levels, respectively.*

Appendix Table 8 Initial and final Soil analysis

| Soil characteristics | Pre-planting | After harvest |
|---|---|---|
| pH | 5.93 | 6.0898 |
| Ppm P | 228.9 | 169.426 |
| | | 7 |
| %N | 0.16 | 0.2120 |
| %OC | 2.36 | 2.647 |
| %OM | 4.07 | 4.5591 |
| K(MEQ/100gm) | 1.15 | 1.1625 |
| CEC(meq/100/gm) | 14.66 | 17.5236 |

Appendix Table 9. Simple correlation on growth, yield and quality traits of tomato

| | PH | PB | DF | DM | FlCl | FLC | FC | FSP | NH | HD | FL | FD | FShI | FPT | NS | SW | PW | PSR | JV | TSS | TA | FN | AFW | TYP | TYH | MYH | UMYH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PH | 1 | 0.62*** | 0.89*** | 0.90*** | 0.71*** | 0.31* | 0.58*** | 0.80*** | 0.06 | 0.50*** | 0.48*** | 0.80*** | -0.24 | 0.06 | 0.31* | -0.05 | 0.15 | 0.10 | 0.55*** | 0.04 | 0.31* | 0.42*** | 0.57*** | 0.58*** | 0.58*** | 0.56*** | 0.20 |
| PB | | 1 | 0.74*** | 0.70*** | 0.97*** | 0.74*** | 0.72*** | 0.55*** | 0.39** | 0.25 | 0.84*** | 0.28* | 0.39** | -0.32* | -0.08 | -0.20 | -0.10 | 0.13 | 0.19 | -0.08 | -0.05 | 0.90*** | 0.42** | 0.95*** | 0.96*** | 0.95*** | -0.14 |
| DF | | | 1 | 0.85*** | 0.83*** | 0.53*** | 0.71*** | 0.75*** | 0.20 | 0.50*** | 0.66*** | 0.69*** | 0.001 | -0.07 | 0.24 | -0.11 | 0.19 | 0.17 | 0.48*** | 0.06 | 0.23 | 0.59*** | 0.59*** | 0.69*** | 0.69*** | 0.67*** | 0.10 |
| DM | | | | 1 | 0.76*** | 0.43*** | 0.63*** | 0.76*** | 0.10 | 0.40*** | 0.52*** | 0.65*** | -0.16 | -0.08 | 0.10 | -0.15 | 0.13 | 0.20 | 0.46** | 0.003 | 0.17 | 0.56*** | 0.50*** | 0.69*** | 0.69*** | 0.67*** | 0.04 |
| FlCl | | | | | 1 | 0.75*** | 0.76*** | 0.61*** | 0.39** | 0.34** | 0.87*** | 0.37** | 0.36** | -0.31* | -0.03 | -0.20 | -0.05 | 0.15 | 0.25 | -0.07 | -0.01 | 0.89*** | 0.49*** | 0.94*** | 0.95*** | 0.94*** | -0.11 |
| FLC | | | | | | 1 | 0.92*** | 0.57*** | 0.63*** | 0.32* | 0.76*** | 0.09 | 0.50*** | -0.34** | -0.10 | -0.17 | 0.04 | 0.18 | 0.13 | -0.04 | -0.09 | 0.84*** | 0.25 | 0.80*** | 0.78*** | 0.78*** | -0.16 |
| FC | | | | | | | 1 | 0.85*** | 0.54*** | 0.47*** | 0.66*** | 0.38** | 0.19 | -0.19 | 0.07 | -0.14 | 0.15 | 0.20 | 0.36* | 0.01 | 0.12 | 0.75*** | 0.38* | 0.77*** | 0.75*** | 0.74*** | -0.03 |
| FSP | | | | | | | | 1 | 0.28* | 0.50*** | 0.40** | 0.65*** | -0.23 | 0.04 | 0.23 | -0.11 | 0.22 | 0.19 | 0.57*** | 0.05 | 0.34* | 0.49*** | 0.41* | 0.59*** | 0.59*** | 0.57*** | 0.08 |
| NH | | | | | | | | | 1 | 0.61*** | 0.49*** | -0.07 | 0.33** | -0.31* | -0.10 | -0.17 | 0.08 | 0.22 | -0.11 | -0.20 | -0.16 | 0.50*** | 0.11 | 0.43*** | 0.41** | 0.41** | -0.19 |
| HD | | | | | | | | | | 1 | 0.29* | 0.45*** | -0.19 | -0.09 | 0.32 | 0.12 | 0.25 | -0.01 | 0.20 | -0.18 | 0.18 | 0.18 | 0.39** | 0.23 | 0.22 | 0.20 | 0.23 |
| FL | | | | | | | | | | | 1 | 0.18 | 0.59*** | -0.45*** | -0.06 | -0.24 | -0.06 | 0.20 | 0.04 | -0.05 | -0.18* | 0.84*** | 0.39 | 0.80*** | 0.83*** | 0.83*** | -0.19 |
| FD | | | | | | | | | | | | 1 | -0.36** | 0.11 | 0.32 | -0.01 | 0.10 | 0.05 | 0.74*** | 0.10 | 0.41** | 0.09 | 0.36 | 0.23 | 0.22 | 0.20 | 0.30* |
| FShI | | | | | | | | | | | | | 1 | -0.47** | -0.37 | -0.27 | -0.23 | 0.17 | -0.27* | -0.12 | -0.42** | 0.53*** | -0.08 | 0.38* | 0.40* | 0.42*** | -0.38** |
| FPT | | | | | | | | | | | | | | 1 | 0.25 | 0.15 | 0.09 | -0.12 | 0.13 | 0.34** | 0.23 | -0.40** | -0.11 | -0.33* | -0.34* | -0.35* | 0.34* |
| NS | | | | | | | | | | | | | | | 1 | 0.59*** | 0.60*** | -0.32 | 0.09 | -0.21 | 0.45** | -0.22 | 0.22 | -0.13 | -0.12 | -0.14 | 0.32 |
| SW | | | | | | | | | | | | | | | | 1 | 0.30* | -0.88*** | -0.17 | -0.11 | 0.23* | -0.31* | 0.0001 | -0.24 | -0.23 | -0.24 | 0.19 |
| PW | | | | | | | | | | | | | | | | | 1 | 0.17 | -0.02 | -0.03 | 0.17 | -0.13 | 0.18 | -0.11 | -0.14 | -0.14 | 0.09 |
| PSR | | | | | | | | | | | | | | | | | | 1 | 0.16 | 0.10 | -0.16 | 0.24 | 0.07 | 0.17 | 0.15 | 0.16 | -0.15 |
| JV | | | | | | | | | | | | | | | | | | | 1 | -0.13 | 0.33* | 0.11 | 0.17 | 0.21 | 0.18 | 0.17 | 0.12 |
| TSS | | | | | | | | | | | | | | | | | | | | 1 | -0.05 | -0.11 | 0.06 | -0.09 | -0.10 | -0.11 | -0.25 |
| TA | | | | | | | | | | | | | | | | | | | | | 1 | -0.18 | 0.12 | -0.05 | -0.08 | -0.09 | 0.23 |
| FN | | | | | | | | | | | | | | | | | | | | | | 1 | 0.27* | 0.94*** | 0.95*** | 0.96*** | -0.30 |
| AFW | | | | | | | | | | | | | | | | | | | | | | | 1 | 0.40** | 0.38** | 0.36** | 0.08 |
| TYP | | | | | | | | | | | | | | | | | | | | | | | | 1 | 0.98*** | 0.97*** | -0.18 |
| TYH | | | | | | | | | | | | | | | | | | | | | | | | | 1 | 0.99*** | -0.23 |
| MYH | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | -0.30* |
| UMYH | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |

PH= Plant height, PB= primary branch, DF= Days to 50% flowering, DM= days to fruit maturity, FlCl= Flower cluster per plant, FLC=flower per cluster, FC=Fruit per cluster, FSP= Fruit set percentage, NH= Number of harvest, HD= Harvest duration, FL= Fruit length, FD= Fruit diameter, FShI= Fruit shape index, FPT=Fruit pericarp thickness, NS=Number of seed per fruit, SW= Seed weight per fruit, PW=pulp weight per fruit, PSR= pulp to seed ratio, JV= juice volume, TSS=total soluble acid, TA= Titratable acid, FN= fruit number per plant, AFW= average fruit weight per plant, TYP= total yield per plant, TYH= total yield per hectare, MYH= marketable yield per hectare, and UMYH= unmarketable yield per hectare.