EVALUATION OF TOMATO (*Lycopersicon esculentum* Mill.) VARIETIES FOR SEED YIELD AND QUALITY UNDER JIMMA CONDITION, SOUTH WESTERN ETHIOPIA

M.Sc. Thesis

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EVALUATION OF TOMATO (*Lycopersicon esculentum* Mill.) VARIETIES FOR SEED YIELD AND QUALITY UNDER JIMMA CONDITION, SOUTH WESTERN ETHIOPIA

Thesis Submitted to School of Graduate Studies Jimma University, College of Agriculture and Veterinary Medicine in Partial Fulfillment of the Requirements for the Degree of Master of Science in Horticulture (Vegetable Science)

By

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DEDICATION

I dedicate this Thesis to my father Balcha Debela, who had been eagerly awaiting my success but passed away suddenly without seeing my fruit, to my mother Desi Dabele, my brothers (Dadi Balcha, Ababa Balcha and Chala Balcha) who have sown an academic interest to my mind.

STATEMENT OF AUTHOR

First, I declare that this thesis is the result of my genuine research work and that all sources of materials used for writing this thesis have been duly acknowledged. This thesis has been submitted to Jimma University College of Agriculture and Veterinary Medicine in partial fulfillment of the requirements for the Degree of Master of Science in Horticulture (Vegetable Science) and is deposited in the Library of the University to be made available to borrowers under the rules and regulations of the Library. I solemnly declare that this thesis has not been submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate. Brief quotations from this thesis are allowed without requiring special permission provided that accurate acknowledgements of sources are made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the Horticulture and Plant Sciences Department or by the Dean of the School of Graduate Studies when in his judgment, the proposed use of the material is in the interests of scholarship. In all other instances, however, permission must be obtained from the author.

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BIOGRAPHICAL SKETCH

The author, Ketema Balcha Debela, was born in Ada'a Barga district of western Shoa zone, Oromia National Regional State from his father Balcha Debela and his mother Desi Debele on June 10, 1988. He attended primary education and junior school Education at Mugher elementary and junior secondary school (1997-2004). He pursued high school Education and preparatory education at Chancho Aba Geda secondary and preparatory school (2005- 2008). He joined Ambo University College of Agriculture in 2009 and graduated on 1stJuly, 2011.With the Degree of Bachelor of Science in Agriculture (Horticulture). In September 2013 he then joined Jimma University School of Graduate Studies to pursue a study leading to the Degree of Master of Science in Horticulture (Vegetable Science).

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LIST OF ACRONYMS

MARC	Melkassa Agricultural Research Center
ESA	Ethiopia Standard Agency
ES	Ethiopia Standard
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database.
CSA	Central Statistical Authority
MoA	Ministry of Agriculture
RCBD	Randomized Complete Block Design
DMRT	Duncan Multiple Range Test
ISTA	International Seed Testing Association
ANOVA	Analysis of variance
SAS	Statistical Analysis System

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Abstract

Tomato is one of the important and widely grown vegetable crops in Ethiopia. However, quality and seed supply is one of the currently gap in the production system. A study was initiated to evaluate nine selected nationally released tomato varieties and one local cultivar for seed yield and seed quality under Jimma condition, Southern Western Ethiopia. The experiment was conducted in Jimma University College of Agriculture and Veterinary Medicine experimental site during 2013/2014 under irrigation condition using a randomized complete block design with three replications. The results indicated significant ($p< 0.01$) variation among the varieties compared with regard to plant height and seedling vigour index, initiation of flowering, Germination percentage, Field emergence percentage, Seedling dry weight (mg). Significantly the highest fruit weight per plant (1.45 kg) and fruit yield per hectare (47.55 tonne) was recorded by Miya while, the minimum marketable yield per hectare (14.88tonne) was recorded from Fetan variety. Bishola recorded significantly the highest seed weight per plant, seed weight per hectare, number of seeds per fruit, give seed weight per fruit, thousand seed weight and fruit girth (5.31 g, 177.26 kg 231, 0.75 g, 3.13 g and 6.25 cm, respectively). The lowest seed yield per hectare was obtained from Fetan (58.1kg). Melkasalsa showed that recorded maximum germination percentage (96%) and field emergence percentage (76%) and lowest seed moisture content (5.5%). Seed weight per plant was significantly and positively correlated with seed weight per hectare ($r=0.95$), seed moisture content ($r=0.47$), germination percentage ($r=0.27$), fruit yield per hectare($r=0.40$) and fruit weight per plant($r=0.40$). However, it was significantly and negatively correlated with seedling dry weight ($r=0.41$). Fruit weight per plant was highly significantly and positively correlated with seed weight per hectare ($r=0.47$) and fruit yield per hectare ($r=.99$). The results indicated that the farmers in the study area can use Bishola variety for high and quality seed yield of tomato although other nationally released and tested variety also gave fairly good seed.

1. INTRODUCTION

Tomato is one of the most popular vegetable crops in the world. It is grown as an annual for both fruit as well as seed purpose. It Rank 1^{st} in the world among vegetables, and accounts for 14% of world vegetable production, over 100 million metric tons/year (FAO, 2010). It is the most widely grown vegetable in the world, being recognized as a reach source of vitamins and minerals. Tomatoes are beneficial to human health for they are rich in minerals, vitamins, essential amino acids, sugars and dietary fibers (Naika *et al*., 2005). Tomatoes are low in calories (20 calories per average size fruit) and an excellent source of iron and vitamins A and C. They also contain small amounts of the B complex vitamins thiamin, niacin, and riboflavin (Chadha, 2006).

In Ethiopia tomato is one of the important and widely grown vegetable crops, both in the rainy and dry seasons for their fruits by smallholder farmers and commercial state and private farms in Ethiopia (Ambecha *et al*., 2012; MoA, 2013; AVRDC, 2014). It is also a source of basic raw material required for fresh consumption and local processing industry for the production of processed tomato like tomato paste, tomato juice and etc. (EIA, 2008).

Lemma *et al*. (2003) indicated that the total production of tomato in Ethiopia has shown a marked increase, indicating that it has became the most profitable crop providing a higher income to small scale farmers compared to other vegetable crops. However, average yield of tomato in Ethiopia low, ranging from 6.5-24.0 metric tonne/ha (Ambecha *et al*., 2012) as compared with average yields of 51, 41, 36 and 34 metric tonne/ha in America, Europe, Asia and the entire world, respectively (FAOSTAT, 2010). The national average of tomato seed yield under farmers' conditions in Ethiopia is also very low, estimated at about 1.2 quintal /ha (Lemma, 2002).

Seeds are one of the least expensive but most important factors influencing yield potential. Crop seeds contain all the genetic information to determine yield potential, adaptation to environmental conditions, and resistance to insect pests and disease. Increasing agricultural production through the use of high quality seed, among other agricultural inputs, has become essential for providing enough food for rising number of people in the world (Barsa, 2006).

Seed produced under controlled condition is likely to be higher yielding and is less likely to harbor pathogen than locally produced seeds (Rice *et al*., 1990; Barsa, 2006).

Seed quality is determined by many factors, principally seed purity and germination. However, many other factors, such as the variety, presence or absence of seed-borne disease, vigor of the seed, and seed size are important when considering seed purchase. Seed lots that have low germination also are less vigorous due to seed deterioration. As seeds deteriorate, loss of vigor precedes loss of viability, so seeds with low germination usually will be less vigorous. Hence, in seed lots with poor germination, those seeds that do germinate often produce weaker seedlings with reduced yield potential (Barsa, 2006; Nemati *et al*., 2010).

According to Lemma (2002), the major production constraints of tomato production in Ethiopia are shortage of varieties and recommended package of information, unknown sources and poor quality seeds, poor irrigation system, lack of information on soil fertility, disease and insect pests, high post harvest loses, lack of awareness of existing improved technologies and poor marketing system.

Supplying of high quality seeds is the basic requirement and it contributes greatly to the success of any crop. Various researchers (Gutterman, 1992; Uniyal *et al*., 2011) have reported variations in seed quality among populations in some plant species to have been attributed to differences in environmental conditions of the mother-plant. Seed yield and quality of tomato is mainly dependent on the variety selected for seed production (George, 1999).

A number of improved varieties and other agronomic packages have been recommended to the users to overcome the low productivity and quality of tomato in the country. According to MoA (2013), Ethiopian National Agricultural Research System (NARS) has released about 25 tomato varieties till 2013. Open pollinated tomato varieties such as 'Melkashola', 'Marglobe', 'Melkasala', 'Heinz 1350', 'Fetan', 'Bishola', 'Eshet' and 'Metadel' had been released nationally and recommended by the Melkassa Agricultural Research Center (MARC) for commercial production and small-scale farming systems in Ethiopia (Lemma, 2002). However due to lack of seed multiplication or distribution system the varieties had not reached farmers.

Previously tomato production has been restricted to certain areas of the country for several reasons such as shortage of seeds of desirable varieties and the lack of a recommendation package regarding production (Lemma, 2002). Smallholder farmers contribute most of the tomato production produced in Ethiopia (Eyob *et al*., 2014), and smallholder farmers are interested in tomato production more than any other vegetables for its multiple harvests potential and for its high profit per unit area (AVRDC, 2014). Attempts have been made to evaluate performances of different tomato varieties at Jimma condition (Menberu *et al*., 2012; Amana *et al*., 2012). According to these authors, the tested tomato varieties have shown very good performance which resulted in high yield and quality fruit.

Tomato producers (smallholder farmers) in the Jimma area, however, are constrained with limited availability of certified seed. The tomato seed is purchased from local shops without clear understanding of its quality, adaptability and viability as well. There is also inconsistency in availability of the seed and the cost is often high. Improving smallholders' tomato production would contribute to enhancing food security and alleviating poverty (Ambecha *et al*., 2012). However farmers need to be supported with improved varieties of sustainable seed supply that could be produced in there locality. No research has been conducted in Jimma area to assess the potential of tomato varieties for quality seed production. In view of this, the present investigation was initiated to assess the effect of varieties (nine varieties and one local) on growth, fruit and seed yield and quality of selected tomato varieties under Jimma condition.

Objective

- To identify best performing tomato (*Lycopersicon esculentum* Mill.) variety (ies) for seed yield and quality under Jimma Condition.

2. LITERATURE REVIEW

2.1 General description of Tomato

2.1.1 Origin

Tomato is one of the most popular and widely grown nutritious vegetables in the world. Most of the cultivated types of tomato belong to *Lycopersicon esculeutum*. Cultivated tomato is generally accepted to have originated in the Americas since all related species of tomato are native to the Andean region consisting of parts of Bolivia, Chile, Colombia, Ecuador and Peru (Jenkins, 1948).

2.1.2. Taxonomy and Botany of the plant

Tomato (*Lycopersicon esculentum L.)* belongs to the family Solanaceae and genus Lycopersicon. The genus includes 12 species (Peralta and Spooner, 2005). It is a true diploid with 2n=24 chromosomes. The plant is annual with herbaceous prostrate stem, heavily branched with alternate, pinnate compound leaves (Rashid and Singh, 2000). The tomato plant has determinate or indeterminate growth habit. In the determinate growth, terminal bud ends in a floral bud and further growth in arrested resulting in dwarf and bushy stature. In indeterminate growth, terminal bud is a leafy bud and terminal and lateral buds continue to grow and there are less production of flowers and fruits on main stem.

2.1.3. Floral Biology and Pollination Habit

Tomato has perfect flowers grouped in compound inflorescences known as a cyme. Each inflorescence usually includes 4 to 8 flowers, and each plant may produce as many as 20 or more successive inflorescences during its life cycle (Tigchelaar, 1986). In most commonly grown field varieties set about 2 to 4 flowers fruits within each cluster. Tomato flower has a 5 to 10 parted calyx which persists until fruit matures. The yellow petals are united in a short tube with five or more lobes which are often recurved. The five stamens are attached to the base of the corolla tube. The long anthers are partly united in the form of a cone surrounding the pistil. The latter consists of a multicelled ovary and a long slender style reaching the tip or projecting from the staminal cone as much as 2 mm with a capitate, single narrow or somewhat bulbous stigma. The buds, flowers, and fruits develop progressively within an individual cluster. There is no definite flowering peak in tomatoes.

Tomato is normally self-pollinated crop (Rashid and Singh, 2000) and self-fertilization is favoured by the position of the receptive stigma within the cone of anthers and the normal pendant position of the flower. Cross-pollination of tomato flowers to the extent of about 5 percent may occur through insects. Tigchelaar (1986) reported rates of natural cross-pollination to vary between 0.5 and 4% in temperate zones.

According to George (1999) some of the reasons that may contribute to cross-pollination are:
i) The possibility of insects introducing foreign pollen to the flower which is common in flowers that have been emasculated for hybrid seed production, (ii) Despite the trend of breeding by developing short-styled cultivars and high rates of self-pollination, there are some cultivars with flowers possessing longer styles, which facilitate cross-pollination. Additionally, high temperature and low irradiation may favor elongation of the style, increasing the chance of cross-pollination.

The minimum isolation distance between different cultivars of tomato for seed production is relatively short (Rashid and Singh, 2000). This is because of the crop's high level of self-pollination. However, the minimum recommended isolation distance between different varieties varies from 30 to 200 m in different countries (George, 1999).

2.2. Soil and Climate requirement

Tomato seed production is highly influenced by environmental factor, particularly temperature which has significant effect on all stages of plant growth and development.
Day and night temperature and the variation between the two has pronounced effect on growth, flowering, fruiting and yield of fruits and seeds in tomato, but the night temperature is a critical factor for fruit set in tomato. Shoaib *et al.* (2012) reported that plants could set fruits abundantly when the night temperature is between 15°C and 20 °C and the day temperature is about 25 °C. Various experiments have revealed that temperature above 32 °C leads to reduction in fruit-set. Fruit set is also reduced at a temperature below 15.5 °C due to poor pollen dehiscence.

Tomato can be grown on a wide range of soils from sandy to clay. The optimum soil pH is 6.5 to 7.0. To obtain good seed yield, fertile soil with efficient drainage and good water holding capacity should be selected (George, 1980).

2.2.1. Seedling Rising

Tomato seedlings are raised in the nursery beds. September to October is the optimum time for sowing seeds in the nursery. Seeds are sown in line on a well-prepared seedbed and lightly covered with soil. After 7 to10 days of sowing, the young seedlings are transplanted on the second bed at a distance of 2to3 cm in both ways. The seed beds should be irrigated immediately after transplanting. The seedlings should be protected from strong sun and heavy rains. Three to four handful of urea dissolved in 30 litres of water can be sprinkled on nursery beds after about a week of transplanting of the young seedlings in the second bed to get healthy seedlings. About 250-300 g seed would provide sufficient seedlings to cover one hectare of land (Rashid *et al.*, 2000).

2.2.2. Land Preparation

Tomato should be planted in well pulverized field by ploughing first with soil turning plough and afterward with 4to5 ploughings. Ploughing should be followed by laddering. Farmyard manures/compost and basic dozes of chemical fertilizers are incorporated into the soil during ploughing (Rashid *et al.*, 2000).

2.2.3. Manures and Fertilizers

Maintaining adequate quantities of nutrients in the soil is important to get good seed yield. It is also reported that for tomato seed crop micro-nutrients like boron, zinc and manganese deserve special attention. The Bangladesh Agricultural Research Institute has recommended 15to 20 tons organic manure, 300 kg urea, 200 kg TSP, 150 kg MP, 100 kg Gypsum and 10 kg borax per hectare. The entire amount of organic manure, TSP, Gypsum, Borax and half of the MP are to be applied during land preparation. The remaining half MP and entire urea are to be applied in three equal installments, first at 15 days after planting, 2^{nd} at flowering and the third at fruit maturity (Rashid *et al.*, 2000).

2.2.4. Planting

Tomato seedlings are ready for planting when they are at 4 to 5 leaf stage in 4to 5 weeks. For seed, tomato is planted in raised beds. Two rows are planted on a 1 m wide raised beds at a spacing of 60 x 60 cm. Planting should be done in the late afternoon followed by light irrigation (Rashid *et al.*, 2000).

2.2.5. Irrigation

Tomato needs very careful irrigation which should be sufficient in right time but water logging should be avoided at all times during the crop growth. Quality of fruits improved by optimum moisture supply during flowering and fruit setting. Heavy irrigation after a long dry spell may result in fruit cracking. Similarly providing irrigation late in the season may result in watery fruits of poor quality. However, irrigation should be given according to the local need (Rashid *et al.*, 2000).

2.2.6. Training, Pruning and Staking

Training of tomato plants with the help of wires or ropes is claimed to result in early ripening, higher yield of better quality fruits and seeds, lesser disease incidence, easier inter cultural operation and harvesting. Pruning side shoots and staking have claimed to have higher yield, uniform and larger fruits (Fernandez, 1952).

2.2.7. Isolation

Isolation distance between different cultivars of tomato for seed production is relatively short. This is because of the crop’s high level of self-pollination. However, the minimum recommended isolation distance between different varieties varies from 30 to 200 m in different countries (George, 1985).According Ethiopia seed standard minimum isolation distance between different cultivars of tomato varies from 50m to100m (ES, 2000).

2.2.8. Rouging

Plants showing different characters to the type must be removed. Rouging is done at different stages of crop growth. Before flowering, plants showing different growth habit and foliage characteristics than the particular variety should be rouged out. Early flowering and fruit setting stage-Off-types are rouged out judging the size and shape of immature fruits. At

Fruiting stage, the off-types are identified examining the fruit characteristics like shape, size, colour etc (Rashid *et al.,* 2000).

2.2.9. Crop rotation

Tomatoes like brinjal crop are susceptible to many of the soil borne diseases and therefore crop rotation must be taken into consideration to prevent pest and disease build-up. Generally a period 3to 4 years should elapse between successive tomato and brinjal crop (Rashid *et al.*, 2000). The Ethiopia seed standard Agency (2000) was report crop rotation for tomato by two years.

2.3. Effect of growing environment on fruit set

Environmental conditions affect fruit set and quality (Delouche, 1980). Tomato seed production is highly influenced by environmental factor, particularly temperature which has significant effect on all stages of plant growth and development (Rashid and Singh, 2000). The authors further stated that day and night temperature and the variation between the two has pronounced effect on growth, flowering, fruiting and yield of fruits and seeds in tomato, but the night temperature is a critical factor for fruit set in tomato.

High day and night temperatures above 32°C and 21°C, respectively, were reported as limiting fruit-set due to an impaired complex of physiological process in the pistil, which results in floral or fruit abscission (Ahmedi and Picken, 1984).

High light intensity accompanied by high temperature is also harmful to fruit-set. High light intensity affects the internal temperature of the reproductive organ of tomato (Kuo *et al*., 1978). High humidity and rainfall decrease the survival rate of tomato plant by encouraging wilt incidence (Hossain *et al*., 1993).

2.4. Tomato seed production

The tomato fruit is a berry, with fleshy pericarp than encloses two or more locules. Most commercial cultivars have three to five locules. The seeds are located inside the locular cavities, attached to the placenta. Each fruit may have 100 to 500 seeds depending on the cultivar and environmental conditions (Tay, 2002).

2.4.1. Hybrid cultivars in tomato

For tomato and pepper, both standard and hybrid cultivars are available. Standard or open pollinated seed is much less expensive than hybrid seed; the reason is because of the type of production, specifically the hybridization process, which is very expensive. Despite their higher cost, the use of hybrid seed is increasing in popularity. In general, hybrid cultivars are preferred because of their vigor, uniformity, disease resistance, stress tolerance and excellent horticultural traits such as long shelf-life. From the breeder's perspective, development of hybrid cultivars allows better control of intellectual property rights including control and protection of parental lines (Tay, 2002).

2.4.2. Seed production under protected structures

Commercial production of tomato and pepper seeds may be performed in the open field or under protected structures, such as greenhouses. Both systems have advantages and disadvantages that must be considered. Factors that affect this decision include the area of production and the type of seed to produce. For example, OP seed probably will be produced in the open field because it is of lower commercial value that does not justify a high investment in resources during production. On the other hand, hybrid seed is of much higher value which justifies its production under protected structures. In areas with favorable weather (i.e. absence of rain and low temperatures), low disease pressure and no isolation problems, hybrid seed production can be performed in the open field without sacrificing seed yield or quality. But, in most cases, it is preferable that hybrid seed production occurs under some type of protection. This can vary from a simple net covering of one row or a group of plants in the field to sophisticated greenhouses with accurate control of environmental conditions, watering and plant nutrition (Nassari *et al*., 2014).

2.4.3. Tomato seed production in the open field

In this case, it is important to select areas with favorable climate, availability of irrigation and low weed, pest and disease pressure. Optimal temperatures depend on the species and genotypes, but, in general, temperatures around 18-27 ^{0}C during the day, and 15-18 ^{0}C during the night are preferred. Higher temperatures cause flower abscission and problems in pollination, fecundity and fruit set. Relative humidity should be greater than 70% in order to favor pollination, but not too high because it could cause pollen agglutination and pollination problems as well as favor disease development (Nassari *et al*., 2014**).**

2.5. Harvest, seed extraction and drying

2.5.1 Harvest timing

The timing of harvest is an important decision in seed production because it affects both yield and seed quality. During their development, seeds reach a peak of maximum quality and it is important to perform harvest at this moment. Some studies have attempted to identify the optimal time for tomato seed harvest. The time of maximum seed dry weight or physiological maturity has been observed between the mature green and breaker stages of tomato fruits. However, maximum seed quality has been obtained when red fruits are harvested. Thus, as a general recommendation for tomato, red fruits should be harvested (Nassari *et al*., 2014).

2.5.2 Harvesting

Seed fruits are allowed to ripen to maturity on the plant. Only completely colored and matured seed fruits are harvested. The mark of the two sepals (calyx) cut off should be checked carefully to ensure that only pollinated fruits are harvested. In hybrid seed production of tomato and pepper, fruits are harvested manually. During this time, only fruits from hand pollinated flowers are picked. Any other fruit must be eliminated because they would be products of self-pollination and, if harvested, they would decrease genetic purity of the seed lot (Nassari *et al*., 2014).

2.5.3 Seed extraction

Once tomato the seeds are extracted from the fruit, they must be separated from the covering gelatinous material. There are several alternatives to achieve this objective:

- For **natural fermentation,** the pulp containing the seeds is left to ferment for up to 3 days at temperatures between 18 and 25^0C (Penaloza, 2001). The time of fermentation depends on the temperature. The mix of gelatinous seeds and juice must be stirred frequently in order to achieve a uniform fermentation rate in the container.

Fermentation is done when the gelatinous coating of the seeds has broken; exceeding the fermentation time negatively affects seed quality (George, 1999).

- **Separation with sodium carbonate** can be used as an alternative to fermentation to separate small lots of seeds. The seeds and pulp are mixed with an equal volume of a 10% solution of sodium carbonate (George, 1999). This mixture is left at room temperature for 18 to 48 hr and the seeds then thoroughly washed. With this method seeds tend to get darker. As a result, this technique is not used in commercial seed lots.

- **Separation with hydrochloric acid** consists in adding around 100 ml of the acid to each 5 kg of pulp and left for 30 minutes (Penaloza, 2001). This method is usually combined with the late stages of fermentation and has the advantage of producing bright, clean seeds.

There is evidence that both sodium carbonate and hydrochloric acid separation methods inactivate the tobacco mosaic virus (TMV) that may de transmitted in the testa of tomato seeds (George, 1999). After separation, tomato seeds are washed. This is accomplished by using long and narrow water troughs that have riffles and intervals (George, 1999). When placed in the trough, seeds sink because of their density, while impurities float and move off with the transported water. Pepper seeds are not fermented and after extraction with the crusher and revolving cylindrical screen, they are washed in a similar way as tomato seeds.

2.5. 4 Seed Drying

Both tomato and pepper seeds must be dried soon after being washed. This may be accomplished in several ways. Independent of the method used, it is important to quickly remove excess water. This can be done by placing the washed seeds inside fine mesh bags and spinning them. Later the seeds are placed in dryers at temperatures that should not exceed 28-30^{0}C because this could affect seed physiological quality. The drying process may extend for 2 to 4 days. During this time, it is important to stir the seeds several times each day so they dry uniformly. Drying of tomato seed is done up to the moisture content of 8% (Agrawal, 1980).

Overall, hybrid seed production of tomato and pepper is an expensive process, due primarily to the work force required for emasculation and pollination. Because of this, hybrid seed of these species is significantly more expensive than for open-pollinated cultivars. Some of the requirements to attain high yields and seed quality are: i) having an adequate knowledge of the reproductive biology of the species, ii) performing good agronomic management of the plants, including harvest at the right time and proper seed extraction and drying, and iii) protecting genetic purity of parental lines and hybrid seed during all phases of the production process.

2.6. Seed Yield and Quality

Tomato seed yields are highly variable, depending upon several factors like the cultivar, season and management practices (Rashid and Singh, 2000). The seed yield will also depend on yield of fresh fruits. However, under sub-continent condition Singh *et al.* (1964) recorded an average yield of tomato seed as 145 kg /ha.

According to Rajashekar *et al.* (2006) Planting seasons and varieties significantly influenced the seed yield per plant and hectare. Higher seed yield per plant (12.93 g) and seed yield per hectare (287.39 kg) was recorded in rabi planted crop and was followed by *kharif* and rabi season. The increased seed yield might be attributed to moderate climatic conditions and free from infestations of pests and diseases. Among the varieties, Nandi recorded significantly higher seed yield per hectare (210.43 kg) than Sankranthi (142.94) and Arka Vikas (138.42 kg). Even though the fruit yield was highest in Vybhav, its seed yield was lowest (95.40 kg/ha) and it was due to its lower seed to fruit ratio (0.18%). The quality parameters *viz.*, 1000 seed weight, per cent germination and seedling vigour index were highly influenced by planting seasons and varieties. Significantly higher 1000 seed weight (2.37 g), germination (90.06%) and s vigour index (1395) was recorded in both *kharif* and *rabi* (2.35 g, 89.75% and 1343 respectively). While, the lowest seed quality parameters were recorded in summer.

Seed quality is the ability of seeds to germinate under a wide variety of environmental conditions and to develop into healthy seedlings (Rashid and Singh, 2000). Quality seed is critical to agricultural production: poor seed limits the potential yield and reduces the productivity of the farmer's labor (Eskandari, 2012). Seed quality is determined by several factors including genetic and physical purity, mechanical damage and physiological conditions, such as viability, germination, dormancy, vigor and uniformity (Dickson, 1980; Hilhorst *et al.*, 2010). The physiological condition of seeds during development and maturation has a strong effect on ultimate seed quality. It is influenced by several environmental factors such as temperature, humidity, light and nutrients during the seed filling and maturation stages, by seed treatments (harvesting and processing) and by accumulated damage (Ouyang *et al.*, 2002). Thus, seed quality is a complex trait governed by interactions between the genome and the environment (Koornneef *et al.*, 2002) and therefore, seed quality can be challenged over the entire seed production chain.

High quality seed lots may improve crop yield in two ways: first, because seedling emergence from the seedbed is rapid and uniform, leading to the production of vigorous plants, and second because percentage seedling emergence is high, so optimum plant population density could be achieved under a wide range of environmental condition (Ghassemi *etal*., 2008). These are the main reasons for farmers, who are interested to buy and cultivate vigorous seeds. Thus, production of high quality seeds is an important strategy for seed producers.

2.6.1. Effect of stage of fruit maturity on seed quality

Production of high quality tomato seeds depends upon the maturity stage (Dias *et al*., 2006). Seed maturation is one of the main components of seed quality and a prerequisite for successful germination and emergence (Perry, 1982). Harvesting of the seed crop at physiological maturity is better as seeds will be having maximum dry weight, higher viability and vigor, besides higher seed yield and yield attributing parameters (Vasudevan *et al.,* 2008). In tomato, seed fruits are allowed to ripen to maturity on the plant, and only completely colored and matured seed fruits are harvested for seed production (Rashid and Singh, 2000).

In developing seeds, the weight continues to increase after flowering. This enhancement is a result of dry mass accumulation (Nedveda and Nikolova, 1999). Increasing seed weight continues until seed reaches to its physiological maturity (Berti and Johnson, 2008).

2.6.2. Effect of Seed quality on germination

The success of germination, seedling establishment and later growth and development of every agricultural crop depends on many factors and high quality seed is a composite term used for all the attributes that add to the performance of a seed (Dickson, 1980; Hilhorst and Koornneef, 2007). Seed quality is also affected by various environmental conditions during seed development, as well as subsequent harvesting methods, handling, and storage conditions. All these environmental factors interact with the seed's genetic make-up (Coolbear, 1995; Koornneef *et al*., 2002).

Germination incorporates those events that commence with the uptake of water by the quiescent dry seed and terminate with the elongation of the embryonic axis (Bewley and Black, 1994). The visible sign that germination is complete is usually the penetration of the structures surrounding the embryo by the radicle. Good seedling establishment and seedling vigor are essential for sustainable and profitable crop production and is therefore considered the most critical stage of a developing crop. Low seed vigor greatly influences both the number of emerging seedlings, and the timing and uniformity of seedling emergence. This has a major impact upon many aspects of crop production that determine cost effectiveness and the inputs required, and also has direct influence on the yield and marketing quality of a crop (Bleasdale, 1967; Finch-Savage, 1995) and subsequent efforts or amount of inputs during later stages of crop development will not compensate for this upshot.

Many studies have shown that initial seedling size is positively related to seed quality, and vigour seeds have better seedling survival rate as well as higher competitiveness (Dolan, 1984; Cornelissen, 1999). The seed supplies the embryo with sufficient nutrition and energy during germination from the food reserves that the seed acquires during the seed filling phase. Thus the seed filling phase plays a crucial role in successful establishment of an autotrophically growing seedling by supplying nutrition and energy and bridging the gap between germination and establishment of green cotyledons that are capable of photosynthesis Natural variation for seedling traits in tomato (Ellis, 1992; Castro *et al*., 2006). Root systems perform the crucial task of providing water, nutrients and physical support to the plant. The length of the main root and the density of the lateral roots determine the architecture of the root system in tomato and other dicots and play a major role in determining whether a plant will succeed in a particular environment (Malamy and Benfey, 1997). Seed vigor may have an essential role in improvement of root architecture during its initial downward growth (Jurado and Westoby, 1992).

In tomato, seed germination and early seedling growth are the most sensitive stages to environmental stresses such as salinity, drought and extreme temperatures (Jones, 1986) and most of the cultivated tomatoes are considered to be sensitive to abiotic stress conditions (Maas, 1986; Foolad *et al*., 1998).

3. MATERIALS AND METHODS

3.1. Description of Study Area

The experiment was carried out at Jimma University College of Agriculture and Veterinary Medicine (JUCAVM), located in Oromia regional state, southwestern part of Ethiopia, 346 km southwest of Addis Ababa at 7^0 42' N latitude and 36^0 50' E longitude with altitude 1710 meters above sea level (ma.sl). The area receives an average annual rain fall of 1250 mm, and average maximum and minimum temperatures of 26.20^{o}C and 11.30^{o}C, respectively and maximum and minimum relative humidity of 91.40% and 37.92% ,respectively (BPEDORS, 2000).

3.1.1. Experimental material

Nine tomato varieties (Table 1); five determinate types (Bishola, Chali, Cochoro, Fetan and Melkasalsa) and four semi-determinate types (Metadel, Miya, Melkashola and Arp tomato $d_{2)}$ and one local cultivar were used for the experiment. Seed of the varieties was obtained from Melkasa Agricultural Research Center (MARC).

Table 1. Description of tomato varieties used for the experiment

Varieties	Altitude	Growth habit	Unique character	Utilization	Maturity days	Research yield Q/ha
Fetan	700-2000	Determinate	Early maturing and concentrated fruit yield	Fresh	78-80	454
Bishola	700-2000	Determinate	Large fruit size Green shoulder fruit color before mature	Fresh	85-90	340
Arp tomato d_2	700-2000	Semi-determinate	Large fruit size, Green shoulder fruit color before mature	Fresh	75 – 80	394
Metadel	700-2000	Semi-determinate	- Medium fruit size - Slightly flatten fruit shape	Fresh	75-80	345
Cochoro	700-2000	Semi-determinate	- Round fruit shape - Green shoulder fruit color before mature	processing	75-90	350
Melkashola	700 -2000	Determinate	- Globular fruit shape	Processing	100-120	430
Chali	700 -2000	Determinate	- Round fruit shape	Processing	110-120	300
Miya	700-2000	Semi-determinate	- High leaf coverage - Hard skin fruit - Plum fruit shape	Fresh	75 – 80	471
Local (RomaVF)	700-200	Determinant	Globulor fruit shape	Fresh	95-100	400
Melkasalsa	700-2000	Determinant	- Small fruit size - Slightly cylindrical fruit shape	Processing	100-110	320

Source: (Meseret, 2012)

3.2 Treatments and Experimental Design

The treatment consisted of nine improved and one local cultivar of tomato. The experimental plots were set out as Randomized Complete Block Design (RCBD) with three replications. Seedlings were carefully transplanted (after 6 weeks or 4-5 true leaves stage) to the experimental plots (2.1 m x 5 m=315 m^2) accommodating 28 plants per plot (four rows) at a recommended spacing of 100 cm between rows and 30 cm between plants (Lemma, 2002).

3.3. Experimental Procedures

3.3.1. Field experiment

The study was conducted under irrigation during December 2013 to March 2014. Seedlings of each variety were raised on nursery bed of 1.69 m^2. The bed was thoroughly prepared and size of length 1.3 m and with width of 1.3 m, 10 rows raised 5 cm from the soil surface to provide good drainage for the removal of surplus water. The seed was sown in rows spaced 15 cm apart and covered lightly with fine soil before irrigation. The beds receive irrigation water every day till germination and latter irrigation were given two times per week and after germination thinning of seedlings at an intra-row spacing of 3 cm was done.

The spacing between two plots in each replication and between adjacent blocks was 50 cm and 100 cm, respectively and the total area required was 315 m^2. Standard agronomic practices, such as weeding, cultivation, irrigation and staking were uniformly applied during growing season to all plots. Similarly, pre-plant granular Di-ammonium Phosphate at a rate 200 kg/ha and Urea fertilizer at rate 100 kg/ha were applied (Lemma, 2002).

Experimental plots were irrigated every day for the first two weeks to secure uniform establishment and then at weekly interval. Disease was managed by application of recommended fungicides (Ridomil@mz 63%) at a rate of 3.5 kg/ha by seven days intervals.

3.3.2. Laboratory experiment

The laboratory experiment was conducted at the plant pathology laboratory at the Jimma University College of Agriculture and Veterinary Medicine (JUCAVM). Seeds of the ten tomato varieties were used in the laboratory to test for seed germination and seed moisture content after harvesting. The laboratory experiment was a 3 × 10 factorial in Completely Randomized Design (CRD). For tomato seed extraction, fruit is placed into a crusher that pulverizes the fruit and separates the gelatinous seed from the remaining fruit tissues by pressing them through screens. The extract containing the gelatinous seed material must still be separated from the remaining pulp in various method hot water treatments. The following model for the RCBD was used for the experiment.

$$Yij = \mu + \alpha i + \beta j + €ij$$

i =treatment, j=1, 2… number of replication

Where:

μ = the overall mean effects

αi = the effects of i^{th} different tomato varieties, i = 1-10

βj = the effects of the j^{th} replication, j = 1-3

€ij = the random error compared for the whole factor

3.4. Data collection

Five plants from each plot was randomly selected and tagged for recording the observation on growth characters.

3.4.1. Growth and flowering characters

Plant height (cm) - The plant height was measured from the base of plant to the terminal growth point of main stem on tagged plants were measured at flower initiation stage. The average height was computed and expressed in centimeters.

Days to initiation of flowering - The days to first flowering in each treatment was recorded and expressed as days to initiation of flowering.

Days to 50 percent flowering - Number of days taken for 50 per cent flowering in the population was recorded and the mean values were expressed in days.

3.4.2. Yield and yield components

Fruit diameter (cm). The five fruits were used for measuring fruit diameter. The diameter was measured at the centre of the fruit with the help of vernier caliper. The mean fruit diameter was computed and expressed in centimeters.

Fruit weight per plant (g). All the red ripe fruits were harvested from five tagged plants at each picking, and added to get total fruit yield. Mean fruit weight was calculated and expressed in grams per plant.

Fruit yield per hectare (ton). The matured fruits were harvested from five tagged plants at each picking and the total fruit yield was recorded, expressed in tonnes per hectare.

Seed weight per fruit (g). In each treatment five fruits from tagged plants were selected randomly and seeds were extracted by fermentation method, dried to 7% moisture and seed weight from five fruits were recorded in grams and mean seed weight per fruit were calculated.

Number of seeds per fruit. In each treatment, five fruits from tagged plants were collected randomly and seeds from fruits each variety were extracted separately by fermentation method. Number of seeds per fruit was counted manually and added, the mean number of seeds per fruit was work out.

Seed weight per plant (g). The seeds were extracted from fully red ripe fruits harvested from five tagged plants by following fermentation method and dried under shade for six to eight days till it reached to constant seed moisture (7%). The total seed weight was recorded and later seed weight per plant in grams was recorded.

Seed yield per hectare (kg). The seed yield per ha was calculated based on seed yield per plot and expressed in kilo gram per hectare.

Thousand seed weight (g). Three samples of 1000-seeds from each treatment were taken at random and weighed, and the mean weight of 1000-seeds was expressed in grams.

3.4.3. Seed quality parameters

Seeds were obtained from each treatment and were evaluated for the following characteristics at JUCAVM laboratory:

Germination (%). Germination test was conducted using three replicates of 100 seeds each in paper towel in the germination room. The germination room was maintained at 25^0C temperature and 95 per cent relative humidity. At the end of 14^{th} day of germination test, the number of normal seedlings in each replication was counted and the germination was calculated and expressed in percentage.

Field emergence percentage. Three hundred seeds were selected at random from each of the treatment and sown in three replications on well-prepared, raised seedbed and water is add at regular interval to maintain adequate moisture in the bed. The number of seedlings emerged in replication 7^{th} to14^{th} day was recorded and expressed as field emergence percent. Emergence percentage was calculated taking into account the number of seedlings emerged 3cm above the soil surface.

Root length (cm). Five normal seedlings in each treatment were randomly selected from field emergence percentage test for measuring root length on 14^{th} day. The selected plants were watering and carefully pulled out without root damage. The root length measured from tip of the primary root to base of hypocotyls and mean root length was express in centimeters

Shoot length (cm). Five normal seedlings used for root length measurement were also used for the measurement of shoot length. The shoot length was measured from the base of the primary leaf to the base of the hypocotyls and mean shoot length was expressed in centimeters.

Seedling dry weight (mg). Five normal seedlings used for measuring seedlings length were taken in butter paper and dried in a hot-air oven maintained at 80^0C temperature for 24 hours. Five seedlings were removed and allowed to cool in a desiccator for 30 minutes before weighing in an electronic balance. The average weight was calculated and expressed as seedling dry weight in milligrams.

Seedling vigour index. The vigour index of seedling were calculated by adapting the method suggested by and expressed in pure number by using following formula. Seedling vigour index = Germination (%) x (Shoot + Root length in cm) (Kumar, 2007).

Seed Moisture Content (%). The moisture content of the seed was determined by the hot air oven method as per ESTA rules grams of seed material from each treatment in three replications were dried in a hot air oven maintained at a temperature of 80^0C for a period of 24 hours (ESA, 2000). Then samples were cooled in desiccators and moisture content was determined by using the formula given below and expressed in percentage.

$$\text{Moisture content (\%)} = \frac{W2 - W3}{W2 - W1} \times 100$$

W1 = Weight of empty aluminum cup (g)

W2 = Weight of empty aluminum cup with seed before drying (g)

W3 = Weight of empty aluminum cup with seed after drying (g)

3.5. Statistical Analysis

Normality was checked before analysis. ANOVA for each character was calculated using a Statistical Software SAS Version 9.2 at 5% probability levels Duncan Multiple Range Test (DMRT) was used to separate means with the significance difference in case of treatments showing significant differences. Correlation analysis was used to evaluate the relation between the recorded response parameters and yield.

4. RESULTS AND DISCUSSIONS

4.1. Growth Parameters

4.1.1. Plant Height

The mean values for plant height are presented in Table 2, and the analysis of variance revealed highly significant (P<0.01) differences among the tomato varieties (Appendix Table 1). The mean value of plant heights of ten varieties ranged from 39.33 to 74.33 cm.

The highest value of plant height was recorded from Arp tomato d $_2$ (74.33 cm). The shortest plant height was observed in Melkasalsa (39.33 cm) and Melkashola (40.66 cm) Bishola, respectively. However, there was no significant difference among these three varieties. Consistent with the results of this study, Hussain *et al*. (2001) reported that there was wide range of difference (61.6-126.5cm) in plant height among the 10 tomato genotypes evaluated in Pakistan. Similarly, Dufera (2013) obtained wide difference (51.5-129.7 cm) for plant height in tomato. Shushay Cherenet and Haile Zibelo (2014) also obtained wide difference (62.1-105.3 cm) in evaluation of nine tomato varieties in western lowland of Tigray, Northern Ethiopia.

4.1.2. Days to flowers initiation

Days to flower initiation showed significant (P<0.05) difference among the varieties (Appendix Table 1). The mean value varied from 31 to 37days (Table 2). The shortest days to flower initiation were recorded from Local, Arp tomato d_2, which were followed by Chali, Metadel and Bishola (31-32 days), all of which were statistically on par. While more days to flowers initiation was recorded by Fetan, Melkashola and Melkasalsa varieties. Emami *et al.* (2013) has found wide difference (103-127 days) in flower initiation comparing 25 tomato varieties in Iran.

4.1.3. Days to 50% flowering

Highly significant (P<0.01) variation was observed among the tomato varieties in the number of days plants to attain 50 % flowering (Appendix Table 1). The mean value varied from 37.66 to 46.33 days (Table 1). Melkashola, Fetan and Miya required more time (46.33, 46.33, 45.33 and days, respectively) to attain 50 % flowering. The Arp tomato d_2 varieties required the shortest time (37 days) to flower. Emami *et al.* (2013) found that there were wide differences (103-127 days) in flower initiation among 25 tomato varieties studied in Iran.

Table 2: Response of tomato varieties for different growth parameters

Varieties	Days to initiation of flowering	Days to 50 per cent flowering	Plant height (cm)
Local	31.00^{c}	38.00^{dc}	63.33^{c}
Arp tomato d_2	31.00^{c}	37.66^{e}	74.33^{a}
Metadel	32.00^{bc}	39.00^{cd}	55.66^{d}
Chali	31.66^{bc}	39.66^{cd}	56.00^{d}
Cochoro	33.33^{bc}	40.00^{c}	50.00^{e}
Melkashola	36.00^{a}	46.33^{a}	40.66^{g}
Miya	33.33^{bc}	45.33^{b}	71.00^{b}
Fetan	37.00^{a}	46.33^{a}	62.66^{c}
Melkasalsa	36.00^{a}	43.66^{b}	39.33^{g}
Bishola	32.00^{c}	39.66^{cd}	44.33^{f}
LSD	1.74	1.82	2.77
CV (%)	5.57	4.68	5.30

4.2. Seed Yield and Yield Components

Analysis of variance revealed that fruit girth, thousand seed weight, fruit yield per plant and fruit yield per hectare varied significantly ($P<0.01$) among the tomato varieties studied (Appendix Table 1).

4.2.1. Fruit Diameter

Analysis of variance showed significant ($P<0.01$) difference among the varieties (Appendix Table 1). The highest fruit girth was observed in Bishola (6.25 cm) (Table 3). This is partially attributed to the fact that ' Bishola ' had large fruit sized than the other cultivars. On the other hand, the lowest value of fruit girth (3.76 cm) was recorded in Melkasalsa. The finding is in line with the report of Shushay and Haile (2014) in fruit diameter for 9 tomato varieties evaluated in lowland Tigray, Norther Ethiopia.

4.2.2. Fruit Yield Per Plant

Fruit weight per plant showed significant difference (P<0.01) among the tomato varieties (Appendix Table 1). The highest fruit weight per plant (1446.64 g) was obtained from Miya variety. While, the lowest values of fruit weight per plant obtained from the varieties Faten (446.46), followed by Metadel (459.75 g), Cochoro (547.70 g), Bishola (566.63) and Malkeshola (574.51 g) all of which were not statistically different from one another (Table 3). The fruit weight per plant in this studied was in accordance with previous reports by Meseret *et al.*, (2012), who reported fruit weight per plant ranging between 1.1 and 1.7 kg. The result is also in line with the finding of Saleem *et al.* (2013), who found highest fruit yield per plant (2.48 kg) evaluating 30 tomato genotypes in Pakistan. Similarly Cherenet *et al*., (2013), reported highest fruit yield per plant (2.10 kg) comparing 36 tomato genotypes.

4.2.3. Fruit Yield Per Hectare

Mean fruit yield per hectare of the varieties ranged from 14.88 tonnes in Fetan to 47.55 tonnes in Miya and was found to be significantly (P<0.01) different among varieties (Appendix Table 1).

The highest fruit weight per hectare (47.55 ton) was obtained from the variety 'Miya' (Table 3). The minimum fruit yield per ha was recorded by Fetan (14.88 ton) which was statistically similar with Metadel (15.32 ton) and Cochoro (18.52tonne) (Table 3). This is in agreement with the finding of Saleem *et al.* (2013) who found the highest fruit yield per hectare (2.48 kg) comparing 30 tomato genotypes in Pakistan. Similarly Cherenet *et al.* (2013) reported highest fruit yield per ha (56.07 ton/ha) evaluating 36 tomato genotypes.

Table 3: Response of Tomato varieties to fruit diameter, fruit weight per plant, and fruit weight per hectare

Varieties	Fruit diameter(cm)	Fruit weight per plant (g)	Fruit yield per hectare (ton)
Local	3.96^{g}	889.82^{b}	29.65^{bc}
Arp tomato d_2	5.73^{b}	761.74^{c}	25.39^{d}
Metadel	5.75^{b}	459.75^{d}	15.32^{g}
Chali	4.83^{f}	812.53^{c}	27.08^{d}
Cochoro	5.57^{c}	547.70^{d}	18.52^{ef}
Melkashola	4.10^{g}	574.51^{d}	19.14^{e}
Miya	5.19^{e}	1446.64^{a}	47.55^{a}
Fetan	5.41^{d}	446.46^{d}	14.88^{g}
Melkasalsa	3.76^{h}	948.07^{b}	31.60^{b}
Bishola	6.25^{a}	566.63^{d}	18.88^{ef}
LSD	0.146	70.303	2.07
CV (%)	3.15	10.03	8.89

4.3. Seed Yield and Its Components

Analysis of variance showed that all seed number per fruit, seed weight per fruit (g), seed yield per plant (g) and seed yield per hectare (kg) showed significant difference ($p < 0.01$) among the Tomato varieties (Appendix Table 1).

4.3.1. Number of Seeds Per Fruit

Bishola variety recorded significantly the highest number of seeds per fruit (231), while the lowest number of seeds per fruit was recorded from Melkasalsa (71) (Table 4). In agreement with this finding, Jiregn Tasisa (2011) reported that there was wide difference (59.47 - 227) in seed number per fruit among the 23 tomato genotypes compared in west Shoa, Ethiopia

4.3.2. Seed Weight Per Fruit

Seed weight per fruit (g) were highly significance difference ($P<0.01$) among the varieties (Table1). The variety Bishola recorded significantly highest seed weight per fruit (0.75 g) and lowest number of seeds per fruit was recorded from Melkasalsa (0.17 g). This is in agreement with the finding of Kumar (2007) who reported varietal difference (0.511 - 0.483 g) in seed weight per fruit for hybrid seed production in tomato (*Lycopersicon esculentum* Mill.) in India.

4.3.3. Seed Yield per Plant

Seed yield per plant (g) showed very highly significance difference ($P<0.01$) among the varieties (Appendix Table 1). Seed yield per plant was significantly the highest in Bishola (5.31 g), followed by Melkasalsa (4.52 g). Significantly the lowest seed yield per plant (1.42 g) was recorded by Fetan variety, however it was not significantly different from Chali (1.94 g), Cochoro (2.04 g) and Metadel (2.14 g). Arp tomato d_2 (2.53g), Malkeshola (2.78), Miya(2.9g) and Local (3.11g) have given comparable seed yield per plant. This indicated selection would be useful in improving seed yield per plant. This is agreement with the finding of Hill and West (1983), who found wide difference (0.88-9.35 g) in seed weight per plant comparing nine tomato cultivars in Florida.

4.3.4. Thousand Seed Weight

Varieties Bishola (3.13 g), followed by Cochoro (3.10 g) had significantly the highest thousand seed weight, while Arp tomato d2 (2.62 g) and Melkashola (2.63 g) had the least thousand seed weight (Table 3). This finding is in agreement with the finding of Kumar (2007) who reported variation of thousand seed weight ranging between 3.69 and 3.79 g) for hybrid seed production in tomato (*Lycopersicon esculentum* Mill.) in India.

4.3.5. Seed Yield per Hectare

Highly significantly variation was observed among the varieties compared (Appendix Table 1). Significantly the highest seed yield per hectare (177.26 kg) was obtained from Bishola variety, followed by Melkasalsa (150.81 kg). The lowest seed yield per hectare was obtained from Fetan (58.1 kg), however, it was not significantly different from Metadel (70.44 kg), Chali (75.92 kg) and Cochoro (79.11 kg). These results are in conformity with finding of Rajashekar *et al.* (2006) who reported different in tomato seed yield per hectare (287.39 kg) in

India. The average seed yield of tomato cultivar is 100-120 kg/ha (Chowdhury, 1976), but good yield of tomato may reach 600-700 kg/ha (Singh *et al*., 1964). On the other hand Agrawal (1980) reported average seed yield of tomato cultivars to vary from 50 to 80 kg per hectare. According to the ESA (2000), tomato seed yield potential in the country was ranged from 1 q/ha to1.5 q /ha.

Table 4. Effect of tomato varieties on seed yield and its component

Varieties	Seed weight per plant (g)	Seed yield per hectare (kg)	Number of seeds per fruit	Seed weight per fruit (g)	Thousand seed weight (g)
Local	3.11^{c}	114.88^{c}	136.33^{e}	0.42^{e}	2.74^{e}
Arp tomato d_2	2.53^{de}	84.70^{ef}	224.66^{b}	0.69^{b}	2.63^{h}
Metadel	$2.14d^{ef}$	70.44^{g}	117.33^{g}	0.26^{i}	2.70^{g}
Chali	1.94^{f}	75.92^{fg}	110.33^{h}	0.38^{g}	2.78^{d}
Cochoro	2.04^{f}	79.11^{fg}	194.33^{c}	0.54^{c}	3.10^{b}
Melkashola	2.78^{cd}	92.88^{e}	88.00^{i}	0.25^{h}	2.62^{h}
Miya	2.9^{cd}	108.00^{dc}	150.33^{d}	0.48^{d}	3.07^{c}
Fetan	1.42^{g}	58.11^{h}	125.33^{f}	0.39^{f}	2.70^{g}
Melkasalsa	4.52^{b}	150.81^{b}	71.00^{j}	0.17^{j}	2.72^{f}
Bishola	5.31^{a}	177.26^{a}	231.00^{a}	0.75^{a}	3.13^{a}
LSD	0.40	12.01	1.63	0.005	0.014
CV (%)	14.90	12.62	1.20	1.36	0.54

4.4. Seed Quality Parameters

Analysis of variance showed that all seed moisture content percent, germination percentage, field emergence percentage, root length (cm), seedling dry weight (mg), showed significant difference (P<0.01) among the tomato varieties (Appendix Table 1). However, there has been no significant difference for shoot length and Seedling vigour index among the varieties (Appendix Table 1 and 2).

4.4.1. Seed moisture content

Moisture content of seeds of the ten tomato varieties showed significant variation ($P < 0.05$). Maximum moisture content (8.03%) was observed in Local, followed by Cochoro (7.40%), Melkashola (7.36%), Miya (7.30%) and Bishola. Significantly the least moisture content from Malkesalsa (5.50%), followed by Arp tomato d_2 (5.90%), however, there has been no significant difference among these two varieties. Such difference was mainly due to genetic make-up of varieties. High seed moisture is more injurious to seed as increases the metabolism and favors the growth of microorganism at higher temperature especially in tropics, where tomato is grown. The results were agreed with national tomato seed moisture content which was maximum 10% (ES, 2000). The result is in agreement with the finding of (Nassari *et al*., 2014) who reported variation in seed moisture content of tomato ranging from 7.6% to 7.0%.

4.4.2. Germination percentage

The germination percentage significantly differed among varieties (Appendix Table 2), and the highest was recorded in Melkasalsa (96%), followed by Cochoro (95.66%), Bishola (94%), Local (93.66%), Chali (93%) and Miya (92.33%), however, there has been no significant difference among each other. Significantly the least germination percentage was recorded in Metadel (85%) which was not significantly different from Melkashola (87.33%) (Table 5).This result was in line with national standard minimum tomato seed germination percentage at laboratory which was ranged from 70% to 85% (ES, 2000). This was due to genetic up of varieties and indicated selection would be useful in improving these characters. This is in agreement with the finding of Hill and West (1983) who found wide difference (96.3% - 71.6%) in germination percentage for 9 tomato cultivars in Florida.

4.4.3. Field emergence (%)

The data on field emergence showed significant difference ($P<0.01$) among the varieties (Appendix Table 2). Maximum field emergence percentage (76 %) was recorded from Melkasalsa, followed by Arp tomato d_2 (74 %) and Cochoro (72%) (Table 5). While the minimum filed emergence (51.33 %) was recorded from Fetan with no statistical deference from Melkashola (55.33 %) (Table 5). The varietal difference for seed quality parameters was mainly due to genetic makeup of varieties. The result of this work is in agreement with the finding of Kumar (2007) who found that the variety Arka Vikas recorded significantly higher field emergence percentage (82.43) compared to Megha (80.44) for hybrid seed production of tomato (*Lycopersicon esculentum* Mill.) in India.

4.4.4. Dry weight of seedlings (mg)

Seedling dry weight (mg) was significantly different among the varieties. Metadel recorded maximum seedlings dry weight (1.07 g). However, this variety is statistically similar with Chali (0.99 gm), Miya (0.98 gm) and Cochoro (0.87 gm). While the lowest seedlings dry weight were obtained from Local (0.72 gm) and Bishola (0.64 gm) Variety (Table 5). In agreement to the finding of this research, Kumar (2007) reported that there were small differences (25.12-25.90 mg) in seedling dry weight for hybrid seed production of tomato (*Lycopersicon esculentum* Mill.) in India.

4.4.5. Root depth (cm)

Analysis of variance showed that there was highly significant differences ($P<0.01$) in root length (Appendix Table 2). The longest root lengths were recorded from Cochoro (13 cm) and Chali (12.33 cm) respectively (Table 5). While the shortest root depth was recorded from Miya (4 cm) which is significantly different from other varieties (Table 5). This is in agreement with the finding of Kumar (2007) who found small difference (6.4-6.59 cm) in the root length of tomato varieties (*Lycopersicon esculentum* Mill.) in India.

Table 5. Effect of tomato varieties on seed quality parameters

Varieties	Parameters				
	Seed moisture content (%)	Germination percentage	Field emergence percentage	Root length (cm)	Seedling dry weight (mg)
Local	8.03^{a}	93.66^{ab}	66.66^{c}	7.66^{d}	0.72^{d}
Arp tomato d_2	5.90^{e}	90.66^{bc}	74.00^{ab}	5.00^{e}	0.76^{cd}
Metadel	6.80^{c}	85.00^{d}	64.00^{c}	9.33^{bc}	1.07^{a}
Chali	6.40^{d}	93.00^{ab}	54.00^{e}	12.33^{a}	0.99^{ab}
Cochoro	7.40^{b}	95.66^{a}	72.00^{ab}	13.00^{a}	0.87^{abc}
Melkashola	7.36^{b}	87.33^{cd}	55.33^{ef}	8.33^{d}	0.90^{bc}
Miya	7.30^{b}	92.33^{ab}	59.33^{edf}	4.00^{f}	0.98^{ab}
Fetan	6.30^{d}	90.66^{bc}	51.33^{f}	9.66^{bc}	0.86^{bc}
Melkasalsa	5.50^{f}	96.00^{a}	76.00^{a}	10.00^{b}	0.75^{cd}
Bishola	7.20^{b}	94.00^{ab}	57.33^{cdef}	8.00^{d}	0.64^{d}
LSD	0.36	4.48	6.52	0.86	0.14
CV (%)	5.68	2.845	11.02	10.54	17.27

4.5. Correlation Coefficient Analysis

Pearson correlation (r) of fruit diameter with other characters showed that highly Significant and positively correlated with seed number per fruit (r=0.75), seed weight per hectare (r=0.56), and seed weight per fruit (r= 0.69). Pearson correlation (r) of thousand seed weight with other characters showed highly Significant and positively correlated with seed number per fruit (r= 0.51) and seed weight per fruit (r=0.52). Seed moisture content was highly significant and positively correlated with seed weight per hectare(r=0.52) and seed weight per plant (r=0.46). Similarly, seed weight per plant was significant and positively correlated with seed weight per hectare(r=0.95). On the other hand, seed weight per plant showed significant and negatively correlated with seedling dry weight (r= -0.41).

Fruit weight per plant was highly Significant and positively correlated with seed weight per hectare (r=0.47) and fruit yield per hectare (r=.99). Fruit weight per plant was highly significant and negatively correlated with root length (r=0.48). In agreement with this finding, Raggase *et al.* (2012) reported that there was highly significant and positively correlated association between fruit weight per plant (r=0.98) and number of fruit per plant (r=0.53) with marketable fruit yield for nine tomato varieties evaluated in Jimma, Ethiopia. Akindele *et al.* (2011) also found highly significant and positively correlated association between fruit weight per plant (r=0.61) and number of fruit per plant (r=0.67) with fruit yield per hectare for nine tomato varieties evaluated in Nigeria.

Number of seeds per fruit was highly significant and positively correlated with seed weight per fruit (r=0.97). Similarly, seed weight per fruit was significant and positively correlated with plant height (r=0.37). But seeds weight per fruit was significant and negatively correlated with days to initiation of flowering (r=0.38) and days to 50% flowering (r=0.43). Seed yield per hectare was Significant and positively correlated with germination percentage(r=0.39) and field emergence percentage (r=0.36). But seeds weight per fruit was highly significant and negatively correlated with seedling dry weight (r=0.48). Days to initiation of flowering was highly significant and positively correlated with Days to 50% flowering (r=0.77) while root length was highly significant and negatively correlated with plant height (r=0.51).

Table 6: Correlation coefficients of seed yield and quality parameters in tomato

	fg	thsdw	Sdwp	mc	fwp	fwha	sdnf	sdwf	sdwha	fid	50%fd	rL	fde	sdw	Ph	ge
fg	-															
thsdwt	0.43*	-														
Sdwp	-0.57*	-0.04ns	-													
mc	-0.38*	0.40*	0.46**	-												
fwp	-0.31ns	0.23ns	0.40*	0.27ns	-											
fwha	-0.32ns	0.23ns	0.40*	0.28ns	0.99**	-										
sdnf	0.75**	0.51**	-0.15ns	0.03ns	-0.09ns	-0.10ns	-									
sdwf	0.69**	0.52**	-0.13ns	0.10ns	-0.01ns	-0.02ns	0.97**	-								
sdwha	0.56**	0.06ns	0.95**	0.52 **	0.47**	0.47**	-0.12ns	-0.08ns	-							
fid	-0.26ns	-0.17ns	-0.13ns	0.00ns	-0.13ns	-0.12ns	-0.45*	-0.43*	-0.21ns	-						
50% fd	-0.24ns	-0.03ns	-0.14ns	0.06ns	0.20ns	0.19ns	-0.44*	-0.387*	0.14ns	0.77**	-					
rL	-0.07ns	0.04ns	-0.24ns	-0.05ns	-0.48**	-0.48**	-0.26ns	-0.29ns	-0.19ns	0.09ns	-0.09ns	-				
fde	-0.10ns	-0.03ns	0.33ns	0.01ns	0.16 ns	0.16ns	0.14ns	0.03ns	0.36*	-0.30ns	-0.3ns	-0.01ns	-			
sdw	0.03ns	-0.10ns	-0.41*	-0.22ns	-0.01ns	-0.00ns	-0.31ns	-0.35ns	-0.48**	0.03ns	0.16ns	0.08ns	-0.22ns	-		
Ph	0.28ns	-0.09ns	-0.15ns	-0.17ns	0.36 *	0.36*	0.35ns	0.37*	-0.14ns	-0.33ns	-0.18ns	-0.51**	0.00ns	0.15ns	-	
ge	-0.16ns	0.44*	0.27*	0.43*	0.30ns	0.31ns	0.18ns	0.24ns	0.39*	0.01ns	-0.11ns	0.19ns	0.23ns	-0.36*	-0.08ns	-

fid =Days to initiation of flowering, 50%fd= Days to 50 per cent flowering, Ph= Plant height (cm) fg =Fruit girth (cm), thsdw=Thousand seed weight (g), fwp= Fruit weight per plant (g), fwha =Fruit yield per hectare (ton) sdwf= Seed weight per fruit (g), Sdnf= Number of seeds per fruit, sdwp =Seed weight per plant (g), sdwha= Seed yield per hectare (kg), mc= hundred seed moisture content percent, ge =Germination percentage, fde= Field emergence percentage (%), rL= Root length (cm) , sdw=Seedling dry weight (mg) , *, ** Significant at the 5% and 1% probability level, respectively

5. CONCLUSION AND RECOMMENDATION

The study comprised nine tomato varieties and one local, evaluated at Jimma University College of Agriculture and Veterinary Medicine with the objective of identifying the variety (ies) for seed yield and quality.

Miya recorded the highest fruit weight per plant (1446.46 g) and fruit weight per hectare (47.55 ton) among the others varieties. Seed weight per plant, seed weight per hectare, number of seeds per fruit, seed weight per fruit, thousand seed weight and fruit diameter were significantly higher in Bishola (5.31 g, 177.26 kg 231, 0.75 g, 3.13 g and 6.25 cm, respectively) compared to the other varieties in tomato seed production. The lowest seed number per fruit and seed weight per fruit were recorded in Melkasalsa (0.17 g and 0.71g, respectively). Cochoro recorded significantly the highest 1000 seed weight (3.13 g), germination percentage (96%) and root length (13 cm) among varieties.

Local, Arp tomato $d_{2,}$ Metadel and Bishola were on par and took the shortest period (31-32 days) to initiate flowers. While the latest Days at flowers initiation was recorded from Fetan variety (37days). Local, Arp tomato $d_{2,}$ Metadel, Chali, Cochoro, Bishola in Days to 50 per cent flowering on par and took the shortest period (40_37.66 days). While, Malkeshola, Miya, Faten, Melkasalsa were statically similar and the late (46.33 days) among the varieties.Correlation analysis showed that the seed weight per plant was significant and positively correlated with seed weight per hectare (r=0.95) Seed moisture content (r=0.47). Fruit weight per plant was highly significant and positively correlated with seed weight per hectare (r=0.47) and fruit yield per hectare (r=.99). Fruit weight per plant was highly Significant and negatively correlated with Root length (r=-0.48). Generally, association of characters indicated that seed weight per plant, seed number per fruit, seed weight per fruit and seed yield per hectare are the most important seed yield components. Therefore, to improve seed yield, selection based on these characters could be possible.

Bishola variety showed the highest value for most response variables compared to the other varieties in tomato seed production. Melkasalsa recorded maximum germination percentage and field emergence percentage and lowest seed moisture content (long time storage). There are other released varieties and should be farther considered. Therefore, the above traits could be considered as selection criteria in tomato improvement program (seed production).

Generally since the experiment is done at single location with single season it is recommended to repeat the experiment with other more varieties, with different seasons and locations. On the other hand, it might be important to consider seed multiplication problems with use of released varieties efficiently and involvement of private sectors to improve seed multiplication.

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7. APPENDIX

Appendix Table 1. Mean square results for growth and yield components of tomato varieties.

		Mean squares					
source of variation	Df	Plant height	Days to flower initiation	Days to 50% flowering	Fruit diameter	Fruit weight/plant	Fruit weight/ha
Block	2	4.63	3.7	11.2	0.050	2595.56	1.80
Varieties	9	447.911**	14.996*	36.941**	2.201**	276562.94**	297.22**
Error	18	8.74	3.44	3.792	0.025	5599.83	4.86

DF =Degrees of freedom, ns = non significant*=significant at 5% probability level and

**=highly significant at 1% probability level.

Appendix Table 2. The mean square result for seed yield parameters of tomato varieties.

	Mean squares				
source of variation	Thousand seed weight	Seed weight/plant	Seed weight/ha	Seed number/ fruit	Seed weight/fruit
Block	0.0000433	0.602	65.534	71.100	0.00040
Varieties	0.120**	4.34**	4237.32**	9112.003**	0.104**
Error	0.00021	0.181	164.10	3.025	0.000029

DF =Degrees of freedom, ns = non significant*=sigificant at 5% probability leveland **=highly s ignificant at 1% probability level.

		Mean squares						
source of variation	df	Shoot length	Root length	Field emergence	Seedling dry	Seedling vigour	Germination Percentage	Seed moisture

				(%)	weight	index		content
Block	2	4.933	24.059	8.4	0.012	136052.800	2.53	0.00148
Varieties	9	5.614^{ns}	3.033**	235.62*	0.056*	156484.75^{ns}	37.12*	0.0178**
Error	18	1.637	0.848	48.25	0.021	33520.393	6.82	0.0014

Appendix Table 3. The mean square result for seed quality parameters of tomato varieties.

DF =Degrees of freedom, ns = non significant*=sigificant at 5% probability leveland **=highly s ignificant at 1% probability level.