EFFECTS OF IRRIGATION FREQUENCY ON YIELD RESPONSE OF TWO COMMONLY GROWN TOMATO VARIETIES AT SHASHOGO WOREDA OF SOUTHERN ETHIOPIA

M.Sc. THESIS

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A THESIS SUBMITTED TO THE SCHOOL OF PLANT AND HORTICULTURAL SCIENCES, COLLEGE OF AGRICULTURE, SCHOOL OF GRADUATE STUDIES, HAWASSA UNIVERSITY

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This is to certify that the thesis entitled '**Effects Of Irrigation Frequency On Yield Response Of Two Commonly Grown Tomato Varieties At Shashogo Woreda Of Southern Ethiopia'**, submitted in partial fulfillment of the requirements for the Degree of **Master of Science** with specialization in **Agronomy** to graduate program of the School of **Plant and Horticultural Sciences**, College of Agriculture, and is a record of original research carried out by **Getahun Lendabo,** under my supervision, and no part of the thesis has been submitted for any other degree.

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As a member of the Board of Examiners of the MSc Thesis Open Defense Examination, we certify that we have read and evaluated the Thesis prepared by Getahun Lendabo and examined the candidate. We recommend that the Thesis is accepted as it fulfilling the Thesis requirements for the Degree of Master of Science in Agriculture (Agronomy).

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DEDICATION

This M.Sc. Thesis is dedicated to my beloved wife, W/ro Genet Lemma, and my beloved parents

STATEMENT OF AUTHOR

First, I declare that this thesis is my original work and that all sources of materials used for this thesis have been duly acknowledged. By my signature below, I declare and affirm that this Thesis is my own work. I have followed all ethical principles of scholarship in the preparation, data collection, data analysis and completion of this Thesis.

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ACRONYMS

ANOVA	Analysis of variance
CSA	Central Statistics of Agency
CWR	Crop Water Requirement
DFFl	Days to first flowering
DFH	Days to first harvest
DFM	Days to first maturity
EIAR	Ethiopian Institute of Agricultural Research
ET	Evapotranspiration
ETB	Ethiopian Birr
GLM	General Linear Model
LSD	Least significant difference test
MFr	Marketable Fruits
m.a.s.l.	Meter above sea level
MARC	Melkasa Agricultural Research Center
MC	Moisture content
MoA	Ministry of Agriculture
MOFED	Ministry of Finance and Economic Development
NARS	Ethiopian National Agricultural Research System
NCPP	Number of clusters per plant
NFlPC	Number of flowers per cluster
NFrPC	Number of fruits per cluster
NFrPP	Number of fruits per plant

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Effects of Irrigation Frequency on Yield Response of Two Commonly Grown Tomato Varieties at Shashogo Woreda of Southern Ethiopia

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ABSTRACT

Tomato is one of the most important vegetable crops widely grown in Ethiopia. It has many nutritional values and considered as high value cash crop in the country. However, its productivity among small scale growers is far below its potential. This is partly due to lack of access and awareness to improved cultivars and agronomic packages. The objective of the study was to identify the response of two tomato cultivars under different irrigation intervals and to determine the optimum irrigation interval. The design was randomized complete block with factorial arrangement of two varieties (variety Galilea and variety Roma VF) and three irrigation intervals (4, 6, and 8 days), with three replications. The experiment was conducted from December 2018 to April 2019, at Shashogo Woreda of Southern Ethiopia. A Data were recorded on Phenological, growth and yield characteristics. Varieties differed significantly ($P<0.05$) in all characteristics, except in number of primary branches and fruit set percentage. Variety Roma VF was earlier by 8 and 13 days in days to first harvest and days to 50% maturity respectively than variety Galilea. Whereas variety Galilea had significantly ($P<0.05$) higher number of secondary branches per plant, clusters per plant, flowers per cluster, fruits per cluster, fruits per plant, marketable fruit yield and total fruit yield than Roma VF. Similarly, irrigation interval of 6 days resulted in higher values in all these characters than irrigation interval of 4 and 8 days. The highest net benefit of ETB 682,584 was obtained from Variety Galilea under irrigation interval of 6 days. Hence, economically attractive combination is to grow variety Galilea under irrigation interval of 6 days. Growing Roma VF under irrigation interval of 6 days might be considered when earliness is needed to meet special market demands.

Keywords:- *Irrigation interval, Marketable yield, Net benefit and Tomato variety*

1. INTRODUCTION

1.1. Background and Justifications

Tomato (*Lycopersicum esculentum* Mill.) belongs to the Solanaceae family and it is originated in the western coastal plain of South America. Tomato is an important vegetable crop grown around the world and is second to potato only (Melkamu *et al.*, 2016). Tomato is rich in nutrients such as vitamins, minerals, and antioxidants, which are important to well-balanced human diet (Falak *et al*., 2011).

In Ethiopia tomato is one of the most important and widely grown vegetable crops, both during the rainy and dry seasons for its fruit by smallholder farmers, commercial state and private farms (Ambecha *et al.*, 2015). In Ethiopia, the crop is grown between 700 and 2000 m above sea level with about 700 to over 1400 mm annual rain fall, in different areas and seasons, in different soils, under different weather conditions. The first record of commercial tomato cultivation in Ethiopia is from 1980s with a production area of 80 ha in the upper Awash by Merti Agro-industry for both domestic as well as export markets (Lemma, 2002). Tomato is one of the most important vegetable crops and widely grown in Ethiopia, ranking 8th in annual national production (CSA, 2016).

The average national yield of tomato is significantly low due to limited access and use of improved commercial varieties and poor production management. Poor agricultural practices and lack of disease and pest resistance varieties lead to low quality and yield of tomato. Insect pests and diseases, not only cause reduction of product and quality, but also increase cost of production (Tesfaye *et al*., 2016).

The importance of tomato is increasing since it is a high value commodity, and has been given top priority in vegetable research in Ethiopia. Small-scale farmers and commercial growers could grow the crop for its fruits in different regions of the country. It is produced both during the rainy and dry seasons under supplemental irrigation (Lemma, 2002). Under these circumstances the total area under tomato production in Ethiopia reaches 9767.78 ha and in Meher season production is estimated to be over 913,013.42 t with the average productivity of 93.47t ha^{-1} (CSA, 2016). Water availability is a major limiting factor of tomato fruit growth and productivity, thus a successful production of tomato requires irrigation.

Irrigation water plays great role in vegetable production as it affects growth, yield and quality of the crop (Janice and Chine, 2008). Water quality and irrigation management practices such as time and frequencies of application are considered as components of major limiting factors of tomato crops production. However, water resources in many parts of the world are limited and thus there is an urgent need to apply effective irrigation strategy to operate under the prevailing conditions of water scarcity (Banjaw *et al*., 2017).

In Ethiopia, several tomato varieties have been released nationally and recommended for large commercial and small scale farming systems. However, these improved varieties along their agronomic packages are not widely being used in the areas with high potential for tomato production. This might be due to either lack of awareness and/or access. Hence, introduction, and evaluation of improved tomato varieties for their adaptability under the potential production areas would likely contribute towards creating awareness and increasing access to growers (Seifudin *et al*., 2016).

Food security is one of the major problems for most Asian and African developing countries. Ethiopia is one of the countries where food security is an important concern. Recurrent drought, unexpected climatic and seasonal variations in rainfall and lack of modern agriculture practices are among the factors that aggravate the problem (FAO, 2003). However, the suitability of the soil and the temperature for economically important crop cultivars along with the availability of easily accessible surface water bodies shows the potential of the country to tackle the food security problems.

Shashogo Woreda, in Hadiya Zone with in Southern Region of Ethiopia is known to have food insecurity problems due to entre erosion, drought and seasonal variations in rainfall. Though there are many surface running water bodies in the woreda, irrigation practice is very scanty. To meet the need of food demand of the population increasing crop production from small farms by growing high value crops, through efficient utilization of irrigation water would likely contribute towards achieving food security in the country. Therefore, the current study was conducted with the following general and specific objectives:-

1.2. General Objective

To identify adaptive tomato variety along with suitable irrigation interval for Shashogo Woreda of Southern Ethiopia

1.3. Specific Objectives

- To determine the effects of irrigation interval on the yield of two tomato varieties
- To determine the optimum irrigation interval for the yield of two tomato varieties
- To evaluate tomato varieties for Shashogo area with optimum irrigation interval.

2. LITERATURE REVIEW

2.1. Origin, Distribution and Production Practices of Tomato

Tomato is indigenous to the Peru and Ecuador region in South America and it probably evolved from *Lycopersicon esculentum* var. cerasiforme, the cherry form. However, it was domesticated and first cultivated in Central America by early Indian civilizations of Mexico. The Spanish explorers introduced tomato into Spain and it was later taken to Morocco, Turkey and Italy. In Italy and France, it was termed “love apple”. Tomato is now one of the most popular and widely grown vegetables around the world (FAO, 2002).

The Ethiopian Institute of Agricultural Research (EIAR) was established in 1966 in which tomato was recognized as a commodity crop. Since 1969 adaptation trial had been carried out but challenged by diseases. Then the first record of commercial tomato cultivation was from 1980 with a production area of 80 ha in the upper Awash by Merit-Agro-industry for both domestic as well as export markets (Lemma, 2002).Today Tomato is considered as one of the high value crops being produced both at commercial farms and at smallholders’ levels (Kelley *et al.*, 2010).

2.2. Variety Selection

Choice of variety is very important since there’s much variation in disease resistance, time till harvest, size and shape of fruits and use. Actually there are two different habits of growth of tomatoes- determinate /dwarf/ and indeterminate /tall- growing/.The determinate varieties of tomato are bush- like, compact in growth, and mature their fruit within a relatively short period (Lemma, 2002).The advantages of these varieties as compared with indeterminate are that staking to support the plants is not a must and mechanical harvest is possible. This group includes varieties with a high content of total soluble solids used for processing as well as varieties for the supply of fresh markets, whereas indeterminate varieties are high in stature, open or rangy in growth and they develop their fruit during a relatively long period of time. These varieties require high labor for maintenance / staking/ (Yebirzaf *et al*., 2016).

The shortage of varieties that are adaptable to different agro-ecologies, poor quality seeds, disease and insect pests, high post-harvest loss, lack of awareness of existing improved technology and poor marketing systems are some of the major constraints associated with tomato production in Ethiopia (Ambecha *et al.,* 2015;MoARD, 2013 and Lemma, 2003). Seed yield and quality of tomato is mainly dependent on the variety selected for seed production. 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 (Lemma, 2003). According to MoARD, (2013) Ethiopian National Agricultural Research System (NARS) has released about 25 tomato varieties so far. Open pollinated tomato varieties such as 'Melkashola', 'Marglobe', 'Melkasalsa', 'Heinz 1350', 'Fetan', 'Bishola', 'Eshet' and 'Metadel' had been released by the Melkassa Agricultural Research Center (MARC) and nationally recommended both for commercial and small-scale production in Ethiopia (Lemma, 2002). However, due to lack of sound seed multiplication and distribution system, the varieties had not reached farmers. Tomato production has been restricted to certain regions of the country for several reasons including the shortage of varieties and the lack of recommended package regarding production (Ketema *et al.***,** 2016).

2.3. Soil and Climatic Requirements of Tomato

Tomato can be grown in a wide range of soils but well drained, light loamy sand to silt loam soils with pH of 5 to 7 are more preferred. The requirement on the organic matter content of the soil is not so high, but soils with medium organic matter content have better yields than soils with low organic matter content (Mohanty and Prosti 2001). Good soil drainage is also important. Tomato roots go deep down into the soil (John *et al*., 2004). Tomatoes, therefore, need a deep soil. Water logging increases incidence of diseases such as bacterial wilt. When there is excess water in the soil the roots cannot breath and they will gradually rot. The crop is moderately sensitive to soil salinity. However, the most sensitive period in relation to salinity is during germination and early plant development stages (MOARD, 2011).

Tomatoes are growing best in a warm and dry climate and not withstand cold weather. Damp air and rain encourage diseases, especially blight. Therefore, in regions, where the air is very damp, it is best to grow tomatoes in the dry season under irrigation. Tomato is a rapidly growing crop with a growing period of 90 to 150 days depending on the specific environmental conditions. It is a day length neutral plant. Even though, the crop can be grown in areas having altitudes below 2500 m above sea level, altitudes ranged from 1100 to 1800 m above sea level are considered to be the best areas for its successful production (FAO, 2002).

The tomato is a warm season crop, killed by freezing temperatures and injured by light frosts. The optimum mean daily temperature for growth is 18 to 25 ^{O}C with night temperatures between 10 and 20 ^{O}C. The crop is very sensitive to frost. Therefore, the crop should be grown in a frost- free period. Temperatures above 25 ^{O}C when accompanied with high humidity and strong wind resulted in weak growth and reduced yield (Wessel-Beaver, 1992). High humidity leads to a high incidence of pests and diseases and fruit rotting. Dry climates are, therefore, preferred for tomato production. Temperatures above $32^{O}C$ during fruit development inhibit the formation of red color (ESHUN *et al*., 2011).

2.4. Crop Water Requirement

2.4.1. Concept of Irrigation

Irrigation is defined as an artificial application of water to irrigated crop fields to supplement the natural sources of water to satisfy the crop water requirements and increase crop yields on sustainable basis without causing damage to the land and soils (Regina *et al*., 2011). The fact is that in many parts of the world including Ethiopia, the amount, frequency and distribution of rainfall, which is the principal source of water for crop production, is becoming more unpredictable and inadequate (FAO, 2002).

2.4.2. Irrigation Agronomy

Irrigation agronomy is simply defined as a branch of agriculture and biology that explores the principles and concepts of plants- soils- water relationships combined with other improved crop management practices to optimize production on sustainable basis without causing damage to the environment (MoARD, 2011). All field crops need soil, water, air and light (sunshine) to grow. Without water crops cannot grow. Too much water is not good for many crops. Irrigation implies the application of suitable water to crops in right amount at the right time (FAO, 1998).

There are two important questions which come to mind: what to do if there is too much rain water? what to do if there is too little rain water? If there is too much rain, the soil will be full of water and there will not be enough air. Excess water must be removed. The removal of excess water - either from the ground surface or from the root zone is called drainage (Doorenbos and Kassam, 1979). If there is too little rain, water must be supplied from other sources; irrigation is needed. The amount of irrigation water which is needed depends not only on the amount of water already available from rainfall, but also on the total amount of water needed by the various crops (FAO, 1986).

2.4.3. Concepts of Irrigation Frequency

The terms, frequency of irrigation and interval of irrigation are closely related and are interchangeable. With higher frequency of irrigation, the interval between two irrigations decreases in a given period, while with lower frequency the interval between two irrigations increases (FAO, 1998).

The term, interval of irrigation indicates the time gap, usually expressed in days, between two subsequent irrigations. Frequency of irrigation and amount of water applied to fruit crops is a common concern among the fruit producers (Mahesh *et al.*, 2016).

The principal objectives of irrigation water management are to make the most effective use of water coupled with higher crop yields and to prevent waste of water and to save it for further use to irrigate new areas. With higher frequency of irrigation, surface soil remain moist for longer periods that leading to higher evapotranspiration losses. Thus, frequency of irrigation should be as low as possible to avoid wastage of irrigation water without affecting the crop growth and final crop yield (Regina *et al.*, 2011). Longer irrigation interval cuts down the number of irrigations during the growing season and ultimately decreases the labor cost for irrigation. Of course, frequent irrigations with smaller depths of water are often more conducive to higher yields than heavier irrigations at longer intervals (Abdul *et al.*, 2015).

Irrigation scheduling refers to the development of schedules for the application or distribution of seasonal or total irrigation water requirement during the growing period of a given crop. The interval between two irrigations should be as wide as possible to save irrigation water, of course, without affecting adversely the crop growth and yield (Candido *et al*., 2000). Scheduling of irrigation is considered to minimize the losses of irrigation water, due to evaporation, leaching, seepage, etc and to maximize the efficient use of available water resources (Janice and Chin, 2008).

Insufficient water supply may result in reduced crop growth, yield and fruit quality due to water stress. Excessive irrigation, on the other hand, may increase nutrient leaching, water-logging problems, incidence of pests and diseases and the associated cost of frequent operation and maintenance of the irrigation system (Regina *et al.*, 2011.) Irrigation frequency will vary according to soil type and weather conditions in the range of 3 to 15 days. Therefore, apply irrigation water every 4-5 days for the first 4 weeks and every 7 days then after (Brouwer and Prins, 1989).

2.4.4. The Benefits of Irrigation

Irrigation of tomatoes can result in higher and more consistent yields, better quality, larger fruit, less blossom-end rot and less cracking (Kassa and Tilahun, 2010). Recent research on processing tomatoes has shown yield increases of up to 81% on a range of soil types with the use of properly scheduled irrigation (Yavuz *et al.*,2007). Tomato yields increased with irrigation in both wet and dry season and on sandy soils as well as on clay loams. On light soils, with their low water holding capacity, the tomato crop can be very responsive to irrigation, but correct scheduling will provide maximum benefit. Proper scheduling is critical when irrigating tomatoes on heavier soils. One consideration for tomatoes grown for paste is that solids, especially soluble solids, tend to be lower when the crop is irrigated (FAO, 2002).

2.4.5. Crop water requirements

Crop water requirements refer to the amount of water required to raise a successful crop with optimum yield in a given period or season. In another words crop water requirement is defined as “the depth of water needed to meet the water loss through evapotranspiration of a disease- free crop growing in large fields under no- restricted conditions including soil water and fertility and aimed at achieving full production potential of the crops under consideration. The crop thus reaches its full production potential under the given environment (FAO, 2002).

Evaporation is a process of losing water to the atmosphere from an open water body and from the soil surface, while transpiration is a process of escaping water to the atmosphere as water vapor through the plant’s leaves and stems (Doorenbos and Pruitt, 1992). The term evapotranspiration (ET) refers to the amount of water lost through evaporation from the wet soil or water and plant surface in the crop field and the water transpired by crop plants including the portion of water used for building of plant tissues. Its value is largely determined by climatic factors; such as solar radiation, temperature, humidity, wind and the environment (Allen *et al.*, 1998).

The influence of climate on crop water needs

A certain crop grown in a sunny and hot climate needs per day more water than the same crop grown in a cloudy and cooler climate (FAO, 2002). There are, however - apart from sunshine and temperature - other climatic factors which influence the crop water need. These factors are the humidity and the wind. When it is dry, the crop water needs are higher than when it is humid. In windy climates the crops will use more water than in calm climates (Allen *et al.*, 1998).

Influence of the crop type on the crop water needs

The crop water need partly depends on the crop type. Crops like maize or sugarcane need more water than crops like millet or sorghum. When determining the influence of the crop type on the daily crop water needs, reference is always made to a fully grown crop; the plants have reached their maximum height; they optimally cover the ground; they possibly have started flowering or started grain setting (FAO, 1998). When the crops are fully grown their water need is the highest. It is the so-called "peak period" of their water needs.

The time of the year during which crops are grown is also very important. A certain crop variety grown during the cooler months will need substantially less water than the same crop variety grown during the hotter months (MOARD, 2011).

Influence of the growth stage of the crop on crop water needs

The crop water need or crop evapotranspiration consists of transpiration by the plant and evaporation from the soil and plant surface. When the plants are very small the evaporation will be more important than the transpiration. When the plants are fully grown the transpiration is more important than the evaporation (Allen *et al.*, 1998).

At planting and during the initial stage, the evaporation is more important than the transpiration and the evapotranspiration or crop water need during the initial stage is estimated at 50 percent of the crop water need during the mid - season stage, when the crop is fully developed (Doorenbos and Pruitt 1992). During the so-called crop development stage the crop water need gradually increases from 50 percent of the maximum crop water need to the maximum crop water need. The maximum crop water need is reached at the end of the crop development stage which is the beginning of the mid-season stage (FAO, 2002).

2.5. Irrigation Agronomic Practices of Tomato Production

2.5.1. Tomato crop Water requirements

The total water requirement of the crop grown in the field for 90- 120 days after transplanting is about 400- 600 mm depending on the climate. The plant produces flowers from bottom to top during the active development of the stem. The crop is most sensitive to water deficit immediately after transplanting and during flowering and then followed by yield formation (FAO, 2002). Water deficit during the flowering period causes flower drop. Moderate water deficit during the vegetative period enhances root growth. For high yield and good quality of produce, the crop needs a controlled supply of water throughout the growing period (May, 1993). Whereas, under water limiting conditions some water savings may be made during the vegetative and ripening periods, water supply should be preferably be directed toward maximizing production per hectare rather than extending the cultivated area (MOARD, 2011).

2.5.2. Irrigation scheduling

Irrigation should provide the crop with the right amount of water, when the crop needs it, at the lowest cost and with least impact on the environment. Irrigation scheduling is the process of determining and planning: when to irrigate, how much water your crop requires, how fast to apply water to your crop (application rate) and how often to irrigate (FAO, 2002b).

The crop performance is sensitive to the irrigation practices. In general, a prolonged severe water deficit limits growth and reduces yield, which can’t be corrected by heavy watering later on. Highest demand for water is during flowering (May, 1993). However, with holding irrigation during this period is sometimes recommended to force less maturing plants into flowering in order to obtain uniform flowering and ripening. Excessive watering during the flowering period, however, has been shown to increase flower drop and reduce fruit set. In addition, excessive watering may cause excessive vegetative growth and a delay in ripening (Gudugi *et al*., 2012). Water supply during and after fruit set must be limited to a rate, which will prevent stimulation of new growth at the expense of fruit development (FAO, 1998).

When water supply is limited, application for a salad crop can be concentrated during periods of transplanting, flowering and yield formation. Irrigation frequency will vary according to soil type and weather conditions in the range of 7 to 15 days. Therefore, apply irrigation water every 4-5 days for the first 4 weeks and every 7 days then after. In general, more frequent irrigation is required on light sand soils than on soils having a high clay fraction. Frequent, but light irrigations improve the size, shape, juiciness and color of the fruit, but total solids /dry matter content/ and acid content will be reduced. However, the decrease in solids will lower the fruit quality for processing (FAO, 2002b). In selecting the irrigation practices consideration must, therefore, be given for the type of end product required. Prolonged water deficits during yield formation period interrupted by heavy irrigation leads to fruit cracking and splitting of the fruit skin (AFFRSA, 2001).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The experiment was conducted in Bonosha area of Shashogo Woreda, within Hadiya Zone of Southern Ethiopia (Fig. 1). The Woreda is found at 224km south of Addis Ababa, the capital city of Ethiopia.

Geographically, the Woreda is located between 7°37′30″-7°29′30″ N and 37°18′- 38°98′ E, with elevation from 1556 to 2443 m.a.s.l. The annual rainfall varies from 857 to 1085 mm; and the annual temperature from 15 to 23°C with mean value of 18°C. The area receives a bimodal rainfall where the small rains are between March and April while the main rains are from June to September (BOFED, 2015). The soil of the area is classified as clay loam with pH of 6.8. Major irrigated crops grown in the Woreda include maize, pepper, tomato, cabbage, onion among the others.

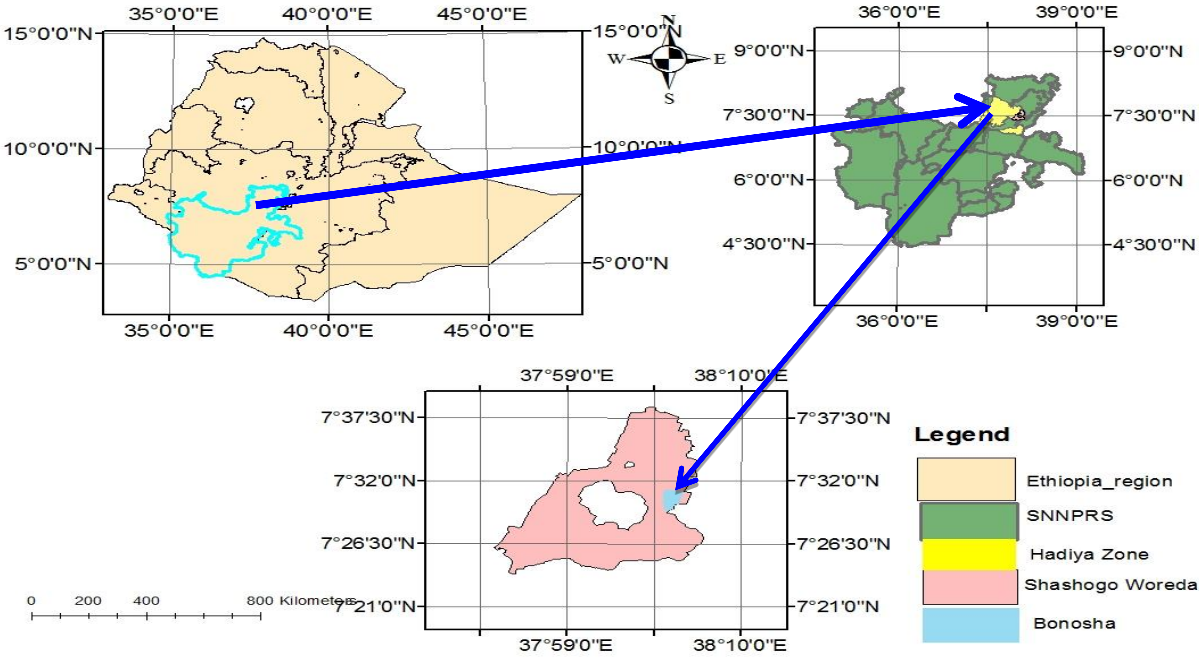

Figure 1 Bonosha Kebele of Shashogo Woreda, within Hadiya Zone of Southern Ethiopia

3.2. Experimental material

Two tomato varieties (Gelilea and Roma VF) were used for the study. Gelilea is a hybrid variety with globular shape of fruits. Its seeds are usually imported from Holland. Whereas Roma VF is an open pollinated variety with pear shaped fruit, released from Melkasa Agricultural Research Center (MARC) in 2007. The seeds of the two varieties, for the current experiment were obtained from Shashogo Woreda Agricultural Office.

3.3. Treatments and Experimental Design

The experimental design was Randomized Complete Block (RCBD) in factorial arrangement with three replications. The factors were two: tomato varieties (Galilea and Roma VF) and irrigation intervals (every three, six and eight days), making six treatment combinations.

Seedlings were raised on a seed bed and transplanted after 35 days from sowing to the experimental plots. A plot area was 12 m^2 (3 m × 4 m) and the spacing was 75 cm between rows and 50 cm between plants (Lemma, 2002). The spacing between two plots within a block and between adjacent blocks was 1 m.

3.4. Experimental Procedures

Field experiment

The study was conducted under irrigation during the dry season (December 2018 to April 2019). Seedlings were raised in nursery beds at Bonosha Kebele Farmers Training Centre (FTC). A seed bed of 8m^2 (2 × 4 m), was well prepared and raised 5cm from the soil surface to provide good drainage for the removal of surplus irrigation water. The seeds were sown in rows spaced 12cm apart and covered lightly with fine soil before irrigation. The beds were irrigated every day until the seeds germinate fully and every three days within a week afterwards.

The land was ploughed by oxen and the big clods were broken into small size. All the weeds and crop residue were removed from the experimental field. After 35 days from sowing, tomato seedlings were transplanted at a spacing of 50 cm between plants within a row and 75 cm between rows, to give a population of 26,666 plants ha^{-1}. Watering was done using furrow irrigation. The whole amount NPS (200kg ha^{-1}) recommended to the area was applied during transplanting while the recommended rate of urea (100kg ha^{-1}) was applied in two equal splits. The first half of urea was applied at the time of planting while the remaining half was applied 21 days after transplanting of seedlings. The experimental plots were kept free from weeds manually and other cultural practices such as disease and insect pest control and staking were performed as per the recommendation for tomato production. Disease was managed by application of recommended fungicides (Ridomil@mz 63%) at a rate of 3.5 kg ha^{-1} in seven days intervals.

3.5. Soil sampling and Analysis.

Pre-planting soil samples from a depth of (0-20 cm) were collected from 8 spots diagonally. The prepared soil samples were composited to one sample and air dried, crushed in a mortar and sieved through a 2 mm sieve. From this mixture, a sample weighing 1 kg was put into a plastic bag (FAO, 2003). Then the composite soil sample was analyzed for the determination of soil texture, soil pH, organic carbon, total nitrogen, and available phosphorus and cat-ion exchange capacity (CEC) using standard laboratory procedures at Hawassa Agricultural Research Institute.

Soil texture analysis was performed by Bouyoucous hydrometer method and Soil pH was measured in water at soil to water ratio of 1:2.5. To determine organic carbon content of the soils, the Walkley and Black (1934) method was employed in which the carbon was oxidized under standard conditions with potassium dichromate in a sulfuric acid solution. Total nitrogen was analyzed by Micro-Kjeldhal digestion method with sulphuric acid (Moreno, 2008). Available phosphorus was determined by the Olsen’s method using a spectrophotometer (Olsen *et al.*, 1980). The CEC was measured after saturating the soil with 1N ammonium acetate (NH_4OAc) and displacing it with 1N NaOAc (Basu, 2011).

3.6. Agronomic data

3.6.1. Phenological and Growth parameters

Days to 50% flowering was recorded as the number of days elapsed from date of transplanting up to the date when 50% of the plants in a plot set flowers. Days to first harvest is recorded as the number of days from transplanting to the first picking day. Days to 50% maturity was recorded as the number of days elapsed from date of transplanting up to the date when 50% of the plants in a plot have ripe tomatoes for the first pick. Plant height (cm) was determined with the use of tape rule measured from the base of the plant above the ground to the last expanded leaf of growing tip, at maturity for randomly selected five plants in each plot. Number of primary branches per plant was determined from five randomly selected plants in net plot area, at the stage of maturity. Number of secondary branches per plant was determined from five randomly selected plants in the net plot area, at the stage of maturity. For both plant height and the number of branches per plant the mean value was used for analysis.

3.6.2. Fruit yield and yield related parameters

The number of clusters per plant was determined from five randomly selected plants at flowering. The number of flowers per cluster was determined from lower, middle and upper clusters of five randomly selected plants. Number of fruits per cluster was determined from lower, middle and upper clusters of five randomly selected plants.

Fruit set percentage is determined as the proportion of the number of fruits to the number of flowers per cluster expressed in percentage. It was calculated using the following formula:-$Fruit\ set\ (\%) = NFrPC / NFlPC\ x100$

Where

$$NFrPC = Number\ of\ fruits\ per\ cluster;$$

$$NFlPC = Number\ of\ flowers\ per\ cluster$$

Fruit weight (g) was determined from five randomly selected fruits at each harvest using sensitive balance, and the mean was used for the analysis. Fruit length (cm) was determined from five randomly selected fruits at each harvest using caliper meter. Fruit width (cm) or diameter was determined from five randomly selected fruits at each harvest using caliper meter.

Fruit yield ($t\ ha^{-1}$) was determined from the sum of fruit weight per plot of successive harvests (kg) and converted to t ha^{-1}. Hence, fruit yield included both marketable and unmarketable yields. The weight of diseased and mechanically damaged fruits was considered as unmarketable yield (t ha^{-1}) while, the weight of fruits free from any visible damages was considered as marketable (Lemma, 2000).

3.7. Data Analysis

The data was subjected to the analysis of variance (ANOVA) using GLM SAS (Statistical Analysis Software) version 9.4. Mean separation was done by least significant difference test (LSD) at 5% probability levels.

4. RESULTS AND DISCUSSION

The Phenological, growth, yield and yield related characters were recorded and analyzed statistically as the response of two tomato varieties (Galilea and Roma VF), under three irrigation intervals (4, 6 and 8 days). The soil physicochemical characters of the experimental field also were recorded. The results and discussion from these are presented in the following.

4.1. Soil physicochemical characteristics

Soils differ in their physical and chemical properties and hence they differ in their suitability for different crops. Therefore, determining the soil physical and chemical characteristics and relating it with known plant requirements is important to get optimum return from the crops. The result revealed that the proportion of sand, silt, and clay contents of the soil were 32.0, 31.2 and 34.8%, respectively at a depth of 0 – 20 cm (Table 1). Thus, according to USDA soil textural classification system, the soil of the experimental field could be classified as clay loam, that is suitable for growing tomatoes.

Table 1. Physical and chemical properties of the soil from experimental site

Physical properties		Content	Chemical properties	Content
Texture:	Sand (%)	32	pH (1:2.5 H_2O)	6.60
	Silt (%)	31.2	Organic carbon (%)	1.8
	Clay (%)	34.8	Organic matter (%)	3.1
			Total N (%)	0.054
Textural class		Clay loam	Available P (mg/kg)	32.98

The results of soil analysis also showed that the soil is slightly acidic with pH values of 6.6. Tomatoes, like most garden vegetables, prefer neutral to slightly acidic soil, with an ideal pH range between 6.0 and 7.0 (Basu, 2011). The OC content of the experimental plot was found to be moderate in the range of 1.00 to 1.80 percent (Table 1). This moderate OC rating indicates that the soil has average structural condition with average structural stability (Olsen *et al.*, 1980).

Soil organic matter is the organic fraction of soil derived from the decayed tissue of plants and animals, and from animal excreta, particularly urine (Walkley and Black, 1934). Generally, soils with comparatively higher organic matter content are considered more fertile than soils low in organic matter content. Soil OM reduces compaction by promoting soil aggregation and increasing porosity (Teklu, 2005). The OM content of the experimental field was 3.1% (Table 1). According to Walkley and Black, (1934) the values of OM range between 1.70 -3.00% is rated as moderate indicating status of an average structural condition with average structural stability. This indicates that the experimental site is naturally fertile for irrigated tomato production.

Nitrogen is one of the major nutrients required for the nutrition of plants. Of the total amount of nitrogen present in soils, nearly 95 - 99% is in the organic form and 1-5% in the inorganic form as ammonium and nitrates (Girma, 2001). The total N recorded from the experimental field was 0.054 (% by weight) where Put the value within 0.03-0.06 % range as medium rating (Basu, 2011 and Egata *et al*., 2016)

The term available phosphorous (AP) refers to the inorganic form, occurring in soil solution and only a small fraction of the total amount present may be available to plants. The available P recorded from the experimental site is in the range of 29.47 to 36.5 mg kg^{-1} of surface soil, indicating presence very high available P (Olsen *et al.*, 1980).

4.2. Phenological Character of Tomato varieties

4.2.1. Days to 50% flowering

The difference among the varieties on days to 50% flowering from transplanting was significant ($P<0.05$) (Appendix Table 2). Variety Galilea took 57 days whereas variety Roma VF took 60 days from transplanting to 50 % flowering (Table 2). Similarly, Bhattarai and Subedi (1996) reported the differences in the days to 50% flowering among different varieties where it ranged from 53 to 74 days after transplanting in open field condition. The difference in the days to 50% flowering among varieties can be attributed to the differences in the genetic makeup of genotypes as reported by Abdelmageed and Gruda (2003). According to Parvej *et al.*, (2010), days to 50% flowering is one of important phenological parameters and determinant factor for growth and productivity of tomato plants.

Differences in irrigation interval resulted in significant change in days to 50% flowering from transplanting (Appendix Table 2). The shortest duration was recorded at the irrigation interval of four days, while the longest at 8 days (Table 2). The interaction effect between variety and irrigation intervals on the days to 50% flowering was not significant.

4.2.2. Days to first harvest from transplanting

The difference among the varieties on days to first harvest from transplanting was significant ($P<0.05$) (Appendix Table 2). The variety Roma VF had shorter period (87.8 days) than the variety Galilea (95.4 days). Bohner and Bangerth (1988) reported that time from transplant to first harvest of plum types and large fruited-type tomatoes ranged between 70 and 90 days, where the earlier maturity occurred for plum types and the late harvesting for large fruited types of tomatoes, which is in agreement with the present findings. Earliness plays important role on fetching higher market price and more income. Even a single day is important for market price and total income from the product. Generally, early varieties are preferred for cultivation on commercial scale (Haileslassie *et al.*, 2016). There was significant increase in days to first harvest from transplanting with the increase in irrigation interval. However, the interaction effect between irrigation frequency and variety was not significant on days to first harvest from transplanting (Appendix Table 2).

Table 2. Effects of irrigation interval and varietal response on phenological characters of tmato

Treatment	Days of fifty % flowering	Days of first harvest	Days of fifty percent maturity
variety			
Galilea	57.2A	95.4A	108.1A
Roma VF	59.4 B	87.8 B	95.8 B
Mean	58.3	91.6	102
LSD	1.5	1.49	3
CV	2.5	1.5	2.8
Irrigation			
4 Days	56.8 B	90.1 B	100.0
6 Days	57.8 B	91.B	103.0
8 Days	60.3A	93.1A	103.0
Mean	58.3	91.6	102
LSD	1.9	1.8	ns
CV	3.4	1.49	2.9

Note: *Values within a column followed by the same letter are not significantly different;* LSD= least of significant at 5% and *CV = Coefficient of variation.*

4.2.3. Days to 50% maturity

The difference in irrigation interval did not result in significant change on days to 50% maturity (Appendix Table 2). However, the difference between varieties in days to 50% maturity was significant (P<0.05). The Variety Roma VF was earlier (95.8 days) than variety Galilea (108.1 days) (Table 2).

Fayaz *et al*. (2007) reported that the delay in flowering can correspondingly lead to the delay in fruit maturity. Days to maturity in tomato is attributed mainly to the genotypic character and also to the extent it is influenced by the environmental factors of any particular growing area. In this experiment the interaction effect from variety and irrigation frequency was not significant on days to 50% maturity (Appendix Table 2).

4.3. Effect of Irrigation Intervals on Growth and yield related Characters of Tomato Varieties

4.3.1. Plant height

The varieties differed significantly (P<0.05) in height (Appendix Table 1). The variety Galilea was taller (73.6 cm) than variety Roma VF (59.8 cm). The taller tomato varieties generally require long growth period and special management practices such as stalking and may also face the incidence of diseases and insect pests. On the other hand the short varieties may not need stalking and their production may require less labor. Generally, the mean height of the tested tomato varieties was in the range of 51.7 -115.5 cm which is in line with the observations of Meseret *et al.*,(2012) who reported the height of tomato varieties ranging from 36.80-126.7cm. There was no significant difference in plant height as the result of irrigation interval. The interaction effect between irrigation interval and varieties was not significant either (Appendix Table 1).

4.3.2. Number of primary and secondary branches

The number of primary and secondary branches per plant is an important parameter which indicates the yielding capacity of tomatoes. In this experiment, the varieties, irrigation frequency and their interaction did not show significant effects on number of primary branches (Table 3). On the other hand, the difference in number of secondary branches between varieties and between irrigation intervals was significant (Table 3); however, the interaction effect was not (Appendix Table 1).

The highest number of secondary branches (23.1) was obtained from variety Galilea, while the lowest (14.2) from variety Roma VF (Table 3). The results of this study coincide with the findings of Sharma and Rastogi (1993), who reported that there is significant variation in number of branches among cultivars of tomato and increasing tendency in the number of branches with an increase in plant height. The results are also in conformity with the work of Shushay*et al.* (2013) and Dufera (2013) who reported that there was significant difference between tomato varieties in the number of secondary branches. According to these authors when the number of secondary branch increased the fruit yield also increased.

Table 3. Effects of irrigation interval on growth and yield related characteristics of tomatoes varieties

Treatment	Plant height	primary branches	secondary branches	clusters per plant	flowers per cluster	Fruits per cluster	Fruit set percentage
Variety							
Galilea	73.6A	7.9A	23.9A	26.4A	5.6A	3.2A	66.8A
Roma VF	59.8 B	8.1A	14.2 B	19.3 B	4.6 B	3.0 B	66.1A
Mean	66.68	8	19	22.85	5.1	3.1	66.4
LSD	3.2	0.52	1.03	1.17	0.57	0.25	ns
CV	4.6	6.2	5.1	4.9	10.6	7.1	3.4
Irrigation interval							
4 days	65.8A	7.6A	18.9 B	22.3 B	5.0A	3.0 B	64.7A
6 days	69.2A	8.4A	20.7A	24.6A	5.5A	3.4A	70.0A
8 days	65.1A	8.0A	17.6 C	21.7 B	4.6A	2.9 B	64.6A
Mean	66.68	8	19.03	22.85	5.1	3.1	66.4
LSD	ns	ns	1.2	1.44	ns	0.31	ns
CV	6.3	9.7	0.4	6.92	9.82	8.5	10.2

Note: *Values within a column followed by the same letter are not significantly different (P < 0.05). LSD= least significant difference and CV = Coefficient of variation, ns = none significant*

4.3.3. Number of clusters per plant

The number of clusters per plant is one of the major parameters for selecting tomato varieties and it determines the yield potential of a variety and preferable fruit size (Pandey *et al.*, 2006). In the present study, the variety Galilea had significantly (P<0.05) higher number of clusters per plant (26.4) than variety Roma VF (19.3), and irrigation interval of 6 days resulted in significantly higher number of clusters than the other intervals (Table 3). However, the interaction effect between variety and irrigation interval on the number of clusters per plant was not significant (Appendix Table 1). In line with the current results several authors also reported wide range of differences in number of fruit clusters per plant in tomato genotypes (Chernet*et al.*,2013; Emani*et al.*,2013 and Aleminew and Tibebu 2017).

4.3.4. Number of flowers per cluster

The analysis of variance indicated that the main effects of variety significantly (*P*<0.05) influenced number of flowers per cluster. However, the main effect of irrigation interval and their interactions did not show significant effect on number of flowers per cluster (Appendix Table1). Of the two varieties, Galilea variety had significantly greater number of flowers (5.6) per cluster than variety Roma VF (4.6) (Table 3). The observed differences between the two varieties might be attributed to the genetic differences. These results resembled with the observation of Meseret*et al.* (2012) where they found 2.27 to 5.89 flowers per cluster in various tomato varieties. Increased production of flowers on tomato plant means high probability in fruit set percentage that may lead to higher yield (Abdelmageed *et al.*, 2003).

4.3.5. Number of fruits per cluster and fruit set percentage

Number of fruits per cluster is one of the major criteria to select better variety for yield and fruit set percent in tomatoes. In the present study, the difference between varieties in number of fruits per cluster was significant (P<0.05), with the variety Galilea having the highest value 3.2 (Table 3). This might be due to the highest number of flowers per cluster and the success of these flowers to develop to fruits. The number of fruits per cluster is affected by the number of flowers per cluster (Meseret*et al*., 2012). It is one of the major criteria to select variety for its yielding potential. In general, the higher the number of fruits per cluster the more fruit yield is though; fruit size also determines the yield estimation (Pandey*et al*., 2006). The effect of irrigation interval on the number of fruits per cluster was significant (P<0.05) with the highest value from the irrigation interval of 6 days (Table 3).

There was no significant variation between varieties in fruit set percentage. The effects of irrigation interval and the interaction of irrigation interval and variety on the fruit set percentage were not significant either. The result from the present study is in contrast with BakiandStomuel, (1993) and Ramin, (1998) who reported considerable range of fruit set percent (1.9 to 46.97%), in the heat tolerant hybrids of tomatoes.

In a varietal experiment, Bhattarai and Subedi, (1996) also reported, the fruit set percent ranging from 1 to 55%. The differences in fruit set in different experiments are due to the differences in varietal character and the irrigation interval. The fruit set range recorded in this study is in agreement with the results of Meseret*et al*., (2012); Khah*et al*., (2006) and Abrar*et al.*,(2011) who indicated that the average fruit set percentage of tomato flowers lays in the ranges between 36.9% and 98.5%.

4.4. Fruit Yield and fruits character

4.4.1. Number of fruits per plants

The difference between varieties in number of fruits per plant was significant ($P<0.05$) (Appendix Table 3). Variety Galilea had greater number of fruits per plants (32.2) than variety Roma VF (Table 4).The difference in irrigation frequency also resulted in significant change on the number of fruits per plant ($P<0.05$). The highest number of number of fruits per plant (30.3) was obtained under irrigation interval of 6 days, while the lowest (26.3) under 8 day interval (Table 4). Some authors stated that the mean number of fruits per plant lay between 4.46 and 98.3 (Eshteshabul *et al*., 2010; Falak*et al*., 2011). Agong*et al*., (2001) reported values between 9.70 and 158.9, while in Ethiopia, Lemma, (2002) reported the fruit number per plant between 26 and 62. The number of fruits per plant is a character affected by the genetic and environmental differences.

4.4.2. Average fruit weight

The varieties differed significantly (P<0.05) in fruit weight (Table 4). The variety Galilea had higher average fruit weight (120.1) than variety Roma VF (64.1). The difference in irrigation frequency also had significant effect on the average fruit weight (P<0.05). The irrigation interval of six days resulted in the highest average fruit weight (102.8), while irrigation interval of 8 days resulted in the least average fruit weight (86.5) (Table 5). Wessel-Beaver, (1992) reported the average fruit weight of tomatoes ranging from 35 to 135.5 cm. Fruit weight is an important parameter for variety selection and customer preference (Meneberu *et al.*, 2011).

Table 4 Effects of irrigation interval and variety on fruit yield and fruit characteristic

Treatment	Fruit per plants	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	unmarketable fruits (t/ha)	Total fruit yield(t/ha)
Variety						
Galilea	32.2A	120.1 A	3.9A	7.7A	28.7A	78.4A
Roma VF	25.4B	64.1 B	3.7 B	6.0B	10.6 B	32.6 B
Mean	28.8	92.08	3.37	6.85	19.6	55.5
LSD	1.67	7.9	0.13	0.2	2.84	4.13
CV	5.53	8.25	3.31	2.85	13.7	7.08
Irrigation interval (days)						
4	29.9A	87.0 B	3.6 B	6.6 B	19.9AB	53.7 B
6	30.3A	102.8 A	4.0A	7.3A	23.3A	65.3 A
8	26.3B	86.5 B	3.7 B	6.7 B	15.7 B	47.6 C
Mean	28.8	92.08	3.78	6.85	19.6	55.5
LSD	2.05	7.9	0.16	0.25	3.4	5.06
CV	6.7	8.03	4.03	2.99	18.6	9.6

Note: *values within a column of each factor followed by the same letter are not significantly different (P < 0.05).LSD=Least significant difference and CV = Coefficient of variation.*

4.4.3. Average fruit length

Size is an important characteristic for tomato commercialization, since a reduced diameter might hinder the product sale. Wessel-Beaver and Scott (1992), believes that several factors might interfere in the tomato fruit quality, but the major factor is water deficiency, since it reduces turgidity and, consequently, the cell expansion process. In the present study, the difference between varieties was significant on the average fruit length ($P<0.05$). The variety Galilea had longer fruits than variety Roma VF (Table 4). Differences in irrigation interval resulted in significant ($P<0.05$) change on the average fruit length and the highest value (4.0) was obtained at irrigation interval of 6 days, while the lowest (3.6) at 4 days interval (Table 4).

The findings of this study are in agreement with Hossain *et al*., (2010) who reported that the average fruit length of tomatoes is ranging from 3.35 to 5.14 cm. Fruit length is an important parameter for variety selection and customer preference (Meneberu *et al.*,2011).

4.4.4. Average fruit width

The varieties differed significantly ($P<0.05$) in the average fruit width. The highest fruit diameter was found from Variety Galilea (7.7 cm), while the lowest (6 cm) from the Roma VF (Table 4). The difference in irrigation interval resulted in significant ($P<0.05$) change on the average fruit width. The highest value of average fruit width (7.3cm) was obtained under irrigation interval of 6 days while the lowest value (6.6cm) under 8 days interval (Table 4).

Depending on the type of variety, tomato fruit width is at the range of 3.2-6.7 cm. The reports of Rashidi and Gholami, (2011) is in line with the findings of the present study (Table 4). The size, length and width of tomato fruits are influenced by the genetic makeup of the varieties and the environment (Atherton and (Rudich, 1986).

4.4.5. Marketable and unmarketable Fruit Yield.

According to Lemma (2002), sun burnt, small sized, cracked, disease affected and insect pest damaged fruits are considered as unmarketable. In the present study the varieties differed significantly ($P<0.05$) in the value of unmarketable yield. The higher unmarketable fruit yield (28.7 tha^{-1}) was recorded in variety Galilea while the least (10.6 tha^{-1}) was recorded in Roma VF (Table 4).

The observed varietal differences of unmarketable yields in the present study might be due to the differences in fruit per carp thickness as indicated by (Capuno *et al.*, 2007). Diseases and insect pests are the major constraints of tomato production at the study area which might be the cause for the observed high values in unmarketable yield.

The difference in irrigation frequency resulted in significant ($P<0.05$) change on unmarketable tomato yields. The highest unmarketable yield (23.3t ha^{-1}) was obtained at irrigation interval of 6 days. On the other hand the least unmarketable yield (15.7 t ha^{-1}) was obtained at irrigation interval of 8 days. Similar findings were reported by Miles *et al*., (2012).

In the present study the interaction effect of variety and irrigation interval had significant effect on marketable yield. The highest marketable yield was obtained from variety Galilea under irrigation interval of six days followed by the same variety under the irrigation interval of four and eight days (Table 5). Marketable fruit yield is the major determinant variable for selection of a particular tomato variety, as it directly affects commercialization and thus income generation of the farms (Pandey*et al*.,2006).

Table 5. The marketable yield response of tomato varieties under different irrigation intervals

		Irrigation Interval			
		4 Days	6 Days	8 Days	mean
Variety	Galilea	46.4B	57.4A	45.3B	49.7
	Roma VF	21.1D	26.7C	18.3D	22.0
	Mean	33.7	42.1	31.8	

4.4.6. Total fruit yield

There was significant difference ($P<0.05$) between varieties in total fruit yield (Table 4). The total fruit yield from variety Galilea was 78.4tha^{-1} in contrast to 32.6tha^{-1} from the Roma VF. The difference in irrigation interval also had significant ($P<0.05$) effect on the total fruit yield of tomatoes. The highest total yield of 65.3tha^{-1} was found under irrigation interval of six days, followed by four days interval with 53.7tha^{-1} and 8 days interval with 47.6 t ha^{-1}. The results are generally in agreement with Lemma (2002) and Meseret *et al*. (2012) who reported the range from 6.46-82.50 t ha^{-1} in their study.

4.5. Economic Analysis

The total cost of production, gross return, net return and benefit cost ratio of growing two tomato varieties under three irrigation intervals was presented in Table 6. The total cost of production decreased with the increase in irrigation interval. The highest net benefit of Birr 682,584 per hectare with least cost production of about Birr 63,941per hectare was obtained from variety Galilea under irrigation interval of 6 days. This means that for every Birr 1.00 invested in, growers can expect to recover the Birr 1.00 and obtain an additional Birr 10.67.

Table 6. Partial budget analysis of Irrigation interval and variety on fruit yield of tomatoes

no	Irrigation frequency	Treatment variety	AvY (kg ha-1)	AAJY(kg ha-1)	Yield price(Birrkg-1	GFB(birr ha-1)	TCV(birr ha-1)	NBF(birr ha-1)
1	4 day Irrgfreq	Galilea	46426	41782.5	13	603538	65571	537967
2	8 day Irrgfreq	Galilea	46426	41783.4	13	589442	62296	527146
3	6 day Irrgfreq	Galilea	57425	51682.5	13	746525	63941	682584
4	4 day Irrgfreq	RomaVF	21139	19025.1	13	274807	41905	232902
5	8 day Irrgfreq	RomaVF	18317.6	16485.8	13	238130	38630	199500
6	6 day Irrgfreq	RomaVF	26656.3	23990.7	13	346532	40275	306257

AvY= average fruit yield; AAJY= average adjusted fruit yield; GFB= gross field benefit of fruit; TCV=total cost that vary; NBF= net benefit from fruit yield

The minimum acceptable marginal rate of return (MRR %) should be between 50% and 100% CIMMYT (1988). In the current study the marginal rate of return is higher than 100% (Table 7), showing that all the treatments are economically important since the MRR is greater than 100%. Hence, the most economically attractive combination of variety and irrigation interval for small scale farmers with low cost of production and higher net benefit is variety Galilea under six days interval of irrigation.

Table 7. The economic cost benefit analysis on tomato yield of two varieties under different irrigation interval

	Treatment Irrigation frequency	variety	TCV (birr ha-1)	NBF (birr ha-1)	MC (birr ha-1)	MB (birr ha-1)	MR	MRR (%)	BCR
1	4 day Irrg freq	Galilea	65571	537967	-	-	-	-	-
2	8 day Irrg freq	Galilea	62296	527146	3275	10821	3.3	330.4	8.5
3	6 day Irrg freq	Galilea	63941	682584	1645	155438	94.49	9449.	10.6
4	4 day Irrg freq	Roma VF	41905	232902	22036	449682	20.40	2040.	5.5
6	8 day Irrg freq	Roma VF	38630	199500	3275	33405	10.2	1020	5.2
5	6 day Irrg freq	Roma VF	40275	306257	1645	106757	64.8	6489.	7.6

TCV = total cost that vary; NBF = net benefit from fruit yield; MC = marginal cost; MB = marginal benefit; MR= marginal rate; MRR = marginal rate of return; BCR = benefit cost ratio

5. SUMMARY, CONCLUSION AND RECOMMEDATION.

Tomato (*Lycospersicon esculentum* Mill.) belongs to the family *Solanaceae*, genus *Lycopersicon*, which is a relatively small genus within the large and diverse family. In Ethiopia, tomato is one of the most important and widely grown vegetable crops, both during the rainy and dry seasons for its fruit. However, its productivity among small scale growers is far below its potential. This is partly due to lack of access and awareness to the improved new cultivars and agronomic packages mainly irrigation. The application of appropriate cultural practices and the choice of cultivars specific to an area are among the main factors that contribute towards increased productivity of tomatoes.

The main aim of the present study was to identify better yielding tomato variety and to determine the optimum irrigation interval for Shashogo Woreda, within Hadiya zone of Southern Ethiopia. The design was randomized complete block in factorial arrangement consisting two tomato varieties (Galilea and Roma VF both are determinate type) and three irrigation intervals (4, 6, and 8 days). with three replications. The experiment was conducted in the year 2019 from January to May, therefore during the irrigation season, at Shashogo Woreda.

The varieties differed significantly on characters viz. plant height, number of secondary branches, number of clusters per plant, number of flowers per cluster, number of fruits per cluster, number of fruits per plant, days to 50% flowering and maturity, days to first harvest, fruit length, fruit diameter, fruit weight, marketable yield, unmarketable yield and total yield. Similarly, the effect of irrigation interval was significant on these characters.

Variety Roma VF was earlier by 8 and 13 days in days to first harvest and days to 50% maturity respectively than variety Galilea. Whereas variety Galilea had significantly

($P<0.05$) higher number of secondary branches per plant, clusters per plant, flowers per cluster, fruits per cluster, fruits per plant, marketable fruit yield and total fruit yield than Roma VF. Irrigation interval of 6 days also resulted in higher values in all these characters than irrigation interval of 4 and 8 days. The increase in marketable yield with the increase in irrigation interval from 4 to 6 days was significant ($P<0.05$). However, further increase in irrigation interval, therefore from 6 to 8 days resulted significant decrease in marketable yield.

The variety Galilea was superior in economic yield than variety Roma VF. The marketable yield of Galilea was superior by 63% than Roma VF. The maximum marketable yield (57.4 t ha-^{1}) and net benefit (ETB 682,584) were obtained from variety Galilea under 6 days of irrigation interval. Therefore, results of the present finding clearly indicated that integration of tomato varieties and irrigation intervals to determine the quality and quantity of the fruit yield of Tomato.

Based on the results of the work the following recommendations are made:

The commercial variety Galilea is recommended for higher marketable and total yield Where earliness is needed with a special market demand the variety Roma VF is recommended. The optimum irrigation interval for higher yield of tomato is six days at Shashogo Woreda conditions. Economically faceable combination is growing variety Galilea under six days of irrigation interval and as the experiment is carried out for one season and in one place, repeating the experiment in time and space is important for the validity of the finding.

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BIOGRAPHY

The author was born on May 20, 1986 in Hadiya Zone at Shashogo Woreda, from his father Lendabo Helamo and his mother Etagegna wchole. He attended his elementary and secondary education at Lisana Elementary and Secondary School in Yekatit 26/67Hossana and preparatory school at Wachemo Preparatory School, Hossana. After completing his high school education in 2003, he joined Jimma University in January 2004 and graduated with B.Sc degree in crop science in July 2006. Soon after graduation, he was employed at Shashogo Woreda Agriculture and Rural Development Office in the position of Irrigation agronomist Expert, and worked there for two years. Secondly, he worked in different positions (expert, team leader, and head of office of Agriculture at Woreda level).and the author participated in different national conferences, workshops, and trainings.

In 2017, the author joined the Graduate School of Hawassa University as a candidate for the degree of Masters of Science majoring in the field of Agronomy.

APPENDIX TABLES

Appendix table 1. Mean squire of vegetative and flower character of tomatoes

Source of variation	Degree of free-dom	Plant height	primary branches	secondary branches	Clusters per plant	flowers per cluster	Fruits per cluster
Block	2	61.06**	2.43**	4.25*	8.74*	0.03ns	0.01ns
Variety	1	859.7***	0.21ns	420.5***	223.31***	4.5**	0.28*
Irrigation interval	2	29.18ns	0.89ns	14.5**	14.3**	0.65ns	0.55**
Variety*Irrigation interval	2	8.44ns	0.05ns	1.65ns	8.96ns	0.53ns	0.02ns
Error	10	9.43	0.25	0.97	1.26	0.3	0.05

ns= non-significant, *= significant at 5% , **= Significant at 1%, ***= Significant at 0.1%

Appendix table 2. Means squire of fruits and phenological character of tomatoes

Source of variation	Degree Of freedom	Fruit set per-centage	Days of fifty % flower	Days of first harvest	Days of fifty percent ma-turity	Fruit per plants
Block	2	35.82ns	12.6*	1.16ns	12.5ns	10.04ns
Variety	1	1.88ns	22.2*	256.8***	672.2***	142***
Irrigation interval	2	58.55ns	19.5**	13.5*	18ns	29.07**
Variety*Irrigation interval	2	31.76ns	1.72ns	7.72ns	4.2ns	3.18ns
Error	10	48.07	2.2	2.03	8.6	2.54

ns= non-significant, *= significant at 5% , **= Significant at 1%, ***= Significant at 0.1%

Appendix table 3. Mean squire of fruits yield and marketable fruit character of tomatoes

Source of variation	Degree Of freedom	Fruit weight(g)	Fruit length(cm)	Fruit width(cm)	Marketable fruit(tha^{-1})	Unmarketable fruits(tha^{-1})	Totalfruit yield(tha^{-1})
Block	2	39.8ns	0.06	0.06ns	9.10ns	44.04*	93.2*
Variety	1	14134.4***	0.16**	11.74***	3451.12***	1480.6**	9452.7***
Irrigation interval	2	516.6**	0.34***	0.83***	176.28***	86.06**	488.7***
Variety*Irrigation interval	2	77.3ns	0.027ns	0.04ns	11.77*	11.63ns	46.1ns
Error	10	57.7	0.015	0.038	2.38	7.32	15.5

ns= non-significant, *= significant at 5% , **= Significant at 1%, ***= Significant at 0.1%

Appendix table 4. Source of variable cost for tomato crop production

no	Source of cost	Roma VF			Galilea		
		4	6	8	4	6	8
1	Labor cost in ETB	12,280	12,280	12,280	12280	12,280	12,280
2	Input cost in ETB						
	Seed in ETB in ETB	3000	3000	3000	26,666	26,666	26,666
	Fertilizer in ETB	4225	4225	4225	4225	4225	4225
	Chemical/pestside/ in ETB	4350	4350	4350	4350	4350	4350
3	Rental value of land per year in ETB	11500	11500	11500	11500	11500	11500
	Irrigation cost	6550	4920	3275	6550	4920	3275
	Total sum	41,905	40,275	38,630	65571	63,941	62,296

APPENDIX FIGURES

Appendix figure 1. After one weak transplanting tomato to expermental plot

Appendix figure 2. The first time to irrigation program schedule.

Appendix figure 3. The first days to count the primary branches

Appendix figure 4. Counting fifty percent flowering

Appendix figure 5. Staking the indeterminate variety

Appendix figure 6. The first harvest

Appendix figure 7. Variety of Roma VF fruit yield that is marketable

Appendix figure 8.Variety of Galilea fruit that is marketable