Int.J.Curr.Res.Aca.Rev.2021; 9(03): 31-46

International Journal of Current Research and Academic Review

ISSN: 2347-3215 (Online) Volume 9 Number 03 (March-2021)

Journal homepage: http://www.ijcrar.com

doi: https://doi.org/10.20546/ijcrar.2021.903.004

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 an adaptive cultivar of tomatoes and to determine the optimum irrigation interval for its growth and yield. A factorial experiment with two varieties (variety Galilea and variety Roma VF) and three irrigation intervals (4, 6, and 8 days), using randomized complete block design with three replications was conducted in 2019 from December to April, 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.

Article Info

Accepted: 15 February 2021
Available Online: 20 March 2021

Keywords

Irrigation interval, Marketable yield, Net benefit, Seedlings, Yield response, Irrigation timing, root development and Tomato variety.

Introduction

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 within Southern Region of Ethiopia is known to have food in security 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, to meet the demand of the population in regards to fruit crops through efficient utilization of irrigation water, this experiment is initiated with the objective to identify an adaptive cultivar of tomatoes and to determine the optimum irrigation interval for its growth and yield.

Materials and Methods

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 15to 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). Major irrigated crops grown in the Woreda includes maize, pepper, tomato, cabbage, onion among the others.

Experimental material

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

Treatments and Experimental Design

The experiment was factorial with two levels of tomato varieties (Galilea and Roma VF) and three levels of irrigation interval (every three, six and eight days), using Randomized Complete Block Design (RCBD) with three replications. Seedlings were raised on a seed bed and transplanted after 4 weeks to the experimental plots. A plot area was 12 m^2 (3 m × 4 m) with spacing of 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.

Experimental Procedures

Field experiment

The study was conducted under irrigation during 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. Seedlings were thinned until an intra-row spacing of 3 cm was achieved. 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 within a row and 75 cm between the rows, to give a population of 26,666 plants ha^{-1}. Watering was done using furrow irrigation. The whole amount NPS ($200kgha^{-1}$) recommended to the area was applied during transplanting while the recommended rate of urea ($100kgha^{-1}$) 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.

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).

Agronomic data

Phenological and Growth parameters

Days to 50% flowering: the number of days elapsed from date of transplanting up to the date when 50% of the plants in plot set flowers were recorded and used for analysis.

Days to 50% maturity: The number of days elapsed from date of transplanting up to the date when 50% of the plants in plot contained horticulturally matured fruits were recorded and used for analysis.

Plant height (cm):was measured from the base of randomly five selected plants in each plot to the main apex at flower initiation stage.

Number of primary branches per plant: from five randomly selected plants were taken in net plot area were counted at the maturity stage and mean values were used for statistical analysis.

Number of secondary branches per plant: from five randomly selected plants were taken in the net plot area and counted at maturity stage and the mean value was used for analysis.

Fruit yield and yield related parameters

Number of clusters per plant: Number of clusters in five randomly selected plants in the plot was counted at 50% flowering.

Number of flowers per cluster: Number of flowers in lower, middle and upper clusters of five randomly selected tomato plants were counted and averaged.

Number of fruits per cluster: Number of fruits in lower, middle and upper clusters of five randomly selected tomato plants were counted and averaged. Fruit set percentage (%): it is 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): The average weight of five randomly selected fruits at each harvest using sensitive balance.

Fruit length (cm): The fruit length of five randomly selected fruits at each harvest was measured using caliper meter and averaged. Fruit width (cm): the diameter of five randomly selected fruits at each harvest was measured using caliper meter.

Days to first harvest: the number of days from transplanting to the first picking day.

Fruit yield ($t\ ha^{-1}$): the Sum of fruit weight per plot from successive harvest (kg) was taken and converted to t ha^{-1}

Marketable and unmarketable yield (tha^{-1}): Diseased, and mechanically damaged fruits were considered as unmarketable (Lemma, 2000), while fruits free from any visible damages were considered as marketable.

Total fruit yield (tha^{-1}): It was obtained by adding marketable and unmarketable fruit yields.

Data Analysis

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

Results and Discussion

Soil Characteristics of Experimental Site

In order to assess soil fertility status through the analysis of some physical and chemical soil properties, soil samples were taken from the experimental sites at a depth of 0-20 cm. The result of laboratory soil analyses on soil texture, soil pH, organic carbon (OC), organic matter (OM),total nitrogen and available phosphorous (AP) are depicted in Table 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 to known plant requirements is important to get optimum return from the crops.

The result revealed that the proportion of sand, silt, and clay continents of the soil were 32.0, 31.2 and 34.8%, respectively at a depth of 0 – 20 cm. Thus, according to USDA soil textural classification system, the soil of the experimental field could be classified as clay loam. 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 between1.70 -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).

Phenological Character of Tomato varieties

Days to 50% flowering

The difference among the varieties on days to flowering from transplanting was significant (P<0.05). Variety Galilea took 57 days whereas, variety Roma VF took 60 days from transplanting to flowering. However, there was only three days difference among the varieties on days to flowering from transplanting. In contrast, Bhattarai and Subedi (1996) reported the flowering days of different varieties ranged from 53 to 74 days after transplanting in open field condition. The difference can be attributed to the genetic makeup of genotypes as reported by (Abdelmageed and Gruda 2003).According to Parvej *et al.*, (2010), days to 50% flowering are 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. 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.

Days to first harvest from transplanting

The difference among the varieties on days to first harvest from transplanting was significant (P<0.05). 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 to 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.

According to Haileslassie *et al.*, (2016) also report that early varieties are generally preferred for cultivation on commercial scale. There was significant increase in days to first harvest from transplanting with the increase in irrigation interval.

Days to50% maturity

The difference in irrigation interval did not result in significant change on days to 50% maturity. 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 of fruit maturity in tomato and furthermore the early or late maturity is attributed by genotypic character and in the extent influenced by the environmental factors of any particular growing area.

Effect of Irrigation Intervals on Growth and yield related Characters of

Tomato Varieties

Plant height

The varieties differed significantly (P<0.05) in height (Table 3). Of the varieties 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 that the height of tomato plants varied between the varieties ranged from 36.80-126.7cm. There was no significant difference in plant height as the result of irrigation interval and interaction between irrigation interval and varieties.

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 tomato.

The varieties, irrigation frequency and their interaction did not show significant effects on number of primary branches(Appendix Table 1). However, the difference in number of secondary branches between varieties, and the difference as the result of the irrigation intervaland interaction effect were significant (Table 3 and 4).

The highest number of secondary branches (26.1) was obtained from variety Galilea at 6 days irrigation interval. However, the lowest number of secondary branches (13.2) was recorded from variety Roma VF at 8 days irrigation interval, which was statistically at par with the same variety and at 4 or 6 days irrigation intervals. 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 also 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 the authors when the number of secondary branch increased the fruit yield also increased.

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, and irrigation interval of 6 days resulted in significantly higher number of clusters than the other intervals (Table 3).

The interaction effect between variety and irrigation interval was significant (p<0.05) on the number of clusters per plant and the highest number of clusters per plant (27.4) was obtained from variety Galilea at irrigation interval of 6 days; while the least (17.7) was from Roma VF at 8 days irrigation interval (Table 4). 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).

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 (P>0.05) 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 due 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).

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 Bakiand Stomuel, (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%.

Fruit Yield and fruits character

Number of fruits per plants

The difference between varieties in number of fruits per plant was significant (P<0.05). Variety Galilea had greater number of fruits per plants (32.2) than variety Roma VF (Table 5). 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 5).

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 that 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.

Average fruit weight

The varieties differed significantly (P<0.05) in fruit weight (Table 5). 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).

According to Wessel-Beaver,(1992) was agreement with the findings of this study who reported that the average fruit weight of tomatoes is ranging from 35 to 135.5 cm. Fruit weight is an important parameter for variety selection and customer preference (Meneberu *et al.*, 2011).

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 5). 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 5).

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).

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 H2O)	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

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

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	90.1C	100.0 A
6 Days	57.8 B	91.B	103.A
8 Days	60.3A	93.1A	103.A
Mean	58.3	91.6	102
LSD	1.9	1.8	3.77
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.

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	7.2
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 B	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	3.95	0.64	1.2	1.44	0.699	0.31	8.9
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

Table.4 Varieties and irrigation interval interaction effects on tomato yield and yield components

		Irrigation interval				
	varieties	4 Days	6 Days	8 Days	mean	CV
Plant height (cm)	Galilea	72.5A	75.1A	73.3A	73.6	6.3
	Roma VF	59.1A	63.3A	56.9B	59.76	6.3
	Mean	65.8	69.2	65.1		
secondary branches	Galilea	23.6AB	26.1A	21.9B	23.86	6.4
	Roma VF	14.1C	15.3C	13.2C	14.2	6.4
	Mean	18.8	20.7	17.5		
Clusters per plant	Galilea	25.1A	27.4A	26.6A	26.36	6.9
	Roma VF	19.5 BC	21.8 B	17.7 C	19.6	6.9
	Mean	22.3	24.6	22.2		
flowers per cluster	Galilea	5.4A	5.7A	5.7A	5.6	9.8
	Roma VF	4.6A	5.2A	4.0 B	4.6	9.8
	Mean	5	5.4	4.8		
Fruits per cluster	Galilea	3.1A	3.5A	3.0A	3.2	8.4
	Roma VF	2.9 A	3.4A	2.7 C	3	8.4
	Mean	3	3.45	2.85		

Table.5 Effects of irrigation interval and variety on fruit yield and fruit characteristics

Treatment	Fruit per plants	Fruit weight(g)	Fruit length(cm)	Fruit width(cm)	Marketable fruit (t/ha)	unmarketable fruits (t/ha)	Total fruit yield(t/ha)
				Variety			
Galilea	32.2A	120.1A	3.9A	7.7A	49.7A	28.7A	78.4A
Roma VF	25.4B	64.1 B	3.7 B	6.0B	22.0 B	10.6 B	32.6 B
Mean	28.8	92.08	3.37	6.85	35.88	19.6	55.5
LSD	1.67	7.9	0.13	0.2	1.6	2.84	4.13
CV	5.53	8.25	3.31	2.85	4.29	13.7	7.08
				Irrigation interval (days)			
4	29.9A	87.0 B	3.6 B	6.6 B	33.8 B	19.9AB	53.7 B
6	30.3A	102.8A	4.0A	7.3A	42.0A	23.3A	65.3 A
8	26.3B	86.5 B	3.7 B	6.7 B	31.8 B	15.7 B	47.6 C
Mean	28.8	92.08	3.78	6.85	35.88	19.6	55.5
LSD	2.05	7.9	0.16	0.25	19.8	3.4	5.06
CV	6.7	8.03	4.03	2.99	5.2	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.

Table.6 Varieties and irrigation interval interaction effects Marketable and unmarketable tomato fruits yield

	varieties	Irrigation interval 4 Days	6 Days	8 Days	mean	CV
Marketable fruit (t/ha)	Galilea	46.4 B	57.4A	45.3 B	49.7	
	Roma VF	21.1 D	26.7 C	18.3 D	22.03	5.2
	Mean	33.75	42.06	31.8		
unmarketable fruits (t/ha)	Galilea	28.1A	34.0A	24.1A	28.73	
	Roma VF	11.7A	12.6A	7.4AC	10.56	18.6
	Mean	19.9	23.3	15.75		
Total fruit yield(t/ha)	Galilea	74.5	91.4A	69.4A	78.4	
	Roma VF	32.9A	39.3A	25.7A	32.6	9.6
	Mean	53.7	65.35	47.56		

Table.7 Partial budget analysis of Irrigation interval and variety on fruit yield of tomatoes

S.No	Treatment Irrigation frequency	variety	AvY (kg ha-1)	AAJY(kg ha-1)	Yield price(Bi rrkg-1	GFB(birr ha-1)	TCV(bi rr 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

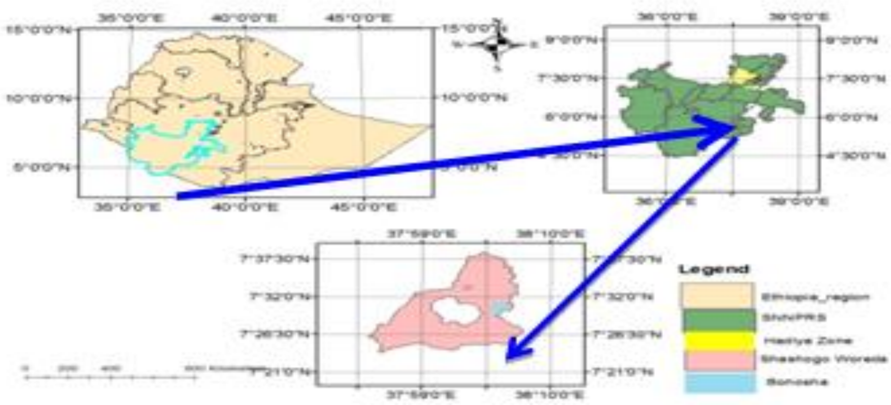
AvY= average fruit yield; AAJY= average adjusted fruit yield; GFB= gross field benefit of fruit; TCV=total cost that vary; NBF= net benefit from fruit yield

Table.8 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 Irrgfreq	Galilea	65571	537967	-	-	-	-	-
2	8 day Irrgfreq	Galilea	62296	527146	3275	10821	3.3	330.4	8.5
3	6 day Irrgfreq	Galilea	63941	682584	1645	155438	94.49	9449.	10.6
4	4 day Irrgfreq	RomaVF	41905	232902	22036	449682	20.40	2040.	5.5
6	8 day Irrgfreq	RomaVF	38630	199500	3275	33405	10.2	1020	5.2
5	6 day Irrgfreq	RomaVF	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.

Fig.1 Bonosha Kebele of Shashogo Woreda, with in Hadiya Zone of Southern Ethiopia



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 5). 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 (6.6 cm) under 8 days interval (Table 5).

Depending on the type of variety, tomato fruit width is at the range of 3.2-6.7 cm Rashidi and Gholami, (2011) which is in line with the findings of the present study (Table 5). The size, length and width of tomato fruits are influenced by the genetic makeup of the varieties and the environment Atherton and (Rudich, 1986).

Marketable and unmarketable Fruit Yield.

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).

The interaction effect between variety and irrigation interval was significant (P<0.05) on marketable fruit yield. The variety Galilea had the highest value recorded at 6 days irrigation interval(57.8 tha^{-1})while the variety Roma VF had the lowest value recorded at irrigation interval of 8 days (18.3 tha^{-1}) (Table 6). 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 5).

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 (23.3tha^{-1}) was obtained at irrigation interval of 6 days. On the other hand the least unmarketable yield (15.7 tha^{-1}) was obtained at irrigation interval of8 days. The same findings were observed fruit quality was immediately affected by the pest and disease (Miles *et al.*, 2012).

Total fruit yield

There was significant difference (P<0.05) between varieties in total fruit yield (Table 5). 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 tha^{-1}. The results are generally in agreement with Lemma (2002) and

Meseret *et al.*, (2012) who reported that total fruit yield of tomato ranging from 6.46-82.50 t ha^{-1} in their study. The interaction effect on marketable yield of tomatoes was significant (P<0.05).Variety Galilea had the highest marketable yield at the irrigation interval of 6 days (Table 6)

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 7. 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 of6 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.

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 8), 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.

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 experiment was factorial with two tomato varieties (Indeterminate Commercial variety Galilea and determinate local variety Roma VF) and three irrigation intervals (4, 6, and 8 days). The design was randomized complete block 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 tha^{-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 local 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.

Conflict of interest

There are no conflicts of competition of interests in this paper.

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How to cite this article:

Getahun Lendabo, Kedir Wulchafo and Desta Abayechaw. 2021. Effects of Irrigation Frequency on Yield Response of Two Commonly Grown Tomato Varieties at Shashogo Woreda of Southern Ethiopia. *Int.J.Curr.Res.Aca.Rev.* 9(03), 31-46. doi: https://doi.org/10.20546/ijcrar.2021.903.004