Determination of irrigation water Requirement and Frequency for Tomato in Efratanagidm District, North Shewa

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ABSTRACT

Information on crop water requirement and frequency of crops is vital for irrigation water planning. Irrigation scheduling is planning when and how much water to apply in order to maintain healthy plant growth during the growing season. It is an essential daily management practice for farmers growing irrigated crops. However, irrigation practice in terms of the amount of water to be used and frequency of application has lacked proper knowledge. The purpose of this study is therefore to deliver the preliminary information on seasonal water requirement of tomato based on the widely used FAO cropwat model. The experiment was conducted at north Shewa Amhara region Efratanagidim District yimilo irrigation site. The experiment was conducted in randomly completed block design with 15 treatments and three replications. Statistically the total depth of water during growth period of tomato at Ataye and the same agroecology was 4431.94m^3/ha to get 48.95t/ha tomato yield gave an additional irrigation land without high yield penalty.

Key words: Tomato, Efratanagidiem, water amount

INTRODUCTION

In Ethiopia, the population is growing rapidly and is expected to continue growing, which inevitably lead to increasing in food demand. Food security is a major concern in many parts of the world including east Africa, Rift valley of Ethiopia where rainfall is unpredictable and unreliable (Tesfaye, 2008). To maintain self-sufficiency in food supply, one viable option is to raise the unit yield. A favorable method for raising yield per unit area is through irrigation.

Reported showed that the crop water requirement of crops correlated with the temperature and irrigation water demand (Kijne, 2010; Surendran et al., 2014). In the future, food and livelihood security may be challenged due to global environmental changes, particularly global climatic changes that evidence has gradually shown to be appearing (Aggarwal and Singh, 2010). Developments in irrigation are often instrumental in achieving high rates of agricultural goals but proper water management must be given due weightage in order to effectively manage water resources. the proper management of existing irrigated areas is important for fulfilling of food security in order to increasing population (Hari Prasad et al., 1996).

Irrigation water management is a crucial component of any irrigation project. Wise use of water resources is becoming the important element in agriculture as the demand for the resource is dramatically increasing because of population pressure and hence feeding the world is a priority issue. Knowledge of crop water requirements is therefore quite helpful for planning a sound irrigation scheduling where water can be used efficiently and effectively.

Operational applications of ET estimates yet heavily rely on the FAO-56 model because of minimum requirement of phonological and standard meteorological inputs (Evett et al., 1995; Kite and Droogers, 2000; Allen, 2000; Eitzinger et al., 2002). In FAO-56 approach, actual ET is calculated by combining reference evapotranspiration (ETo) and Kc. The Food and Agriculture of the United Nations has been extensively working on models that are capable of estimating crop water requirement and exercising irrigation scheduling of crops for any irrigation project for the last thirty years. The models have been widely used in the research, academia and developments sectors.

Understanding crop water needs is essential for irrigation scheduling and water efficient use in an arid region (Parry et al., 2005). Further, with increasing scarcity and growing competition for water, judicious use of water in agricultural sector will be necessary (Ali, 2010). Predicting water needs for irrigation is necessary for the development of an adequate water supply and the proper size of equipment. In our study area consistent information on irrigation water use is still lacking. CROPWA is a FAO model for irrigation management designed by Smith (1991) which integrates data on climate, crop and soil to assess reference evapotranspiration (ETo), crop evapotranspiration (ETc) and irrigation water requirements

The CROPWAT model a simple water balance model that allows the simulation of crop water stress conditions and estimations of yield reductions based on well-established methodologies for determination of crop evapotranspiration (FAO, 1998) and yield responses to water (Doorenbos and Kassam, 1979).

In Ethiopia, the major portion of irrigation water management is traditional where farmers are irrigating as long as the water is available, without considering whether it is above or below the optimum of the crop water requirement. For large dams, the information of crop water requirement of the proposed crops is usually used for design purposes and it is not exercised on the real duty of irrigation operation, however. Moreover, in areas where, farmers are cultivating on small scale, the same information is critically limiting and more water is believed to be wasted (Roth G. 2014).

Irrigation scheduling is planning when and how much water to apply in order to maintain healthy plant growth during the growing season. It is an essential daily management practice for a farm manager growing irrigated crops. Proper timing of irrigation water applications is a crucial decision for a farm manager to: 1) meet the water needs of the crop to prevent yield loss due to water stress; 2) maximize the irrigation water use efficiency resulting in beneficial use and conservation of the local water resources; and 3) minimize the leaching potential of nitrates and certain pesticides that may impact the quality of the groundwater.

Effective irrigation is possible only with regular monitoring of soil water and crop development conditions in the field, and with the forecasting of future crop water needs. Delaying irrigation until crop stress is evident, or applying too little water, can result in substantial yield loss. Applying too much water will result in extra pumping costs, wasted water, and increased risk for leaching valuable agrichemicals below the rooting zone and possibly into the groundwater.

Irrigation criteria, in terms of frequency of irrigation and amount of application per irrigation, seasonal net irrigation requirement and gross irrigation requirement for most of the lowland crops that are grown in the Middle Awash region of Ethiopia have been quantified by Melka Werer Research Centre. However, there was little effort undertaken in the highlands of Ethiopia especially in Amhara region. Crop water use studies which was conducted in some other area are not adopted because it highly location specific.

In North Shewa as such there is no an attempt to determine crop water requirements of irrigated crops except study conducted at Shewarobit for onion and pepper and at Bakelo for wheat and potato to estimate crop water requirements. The aim of this research was therefore to estimate the net irrigation requirement of tomato (Lycopersicon*esculentum) and* estimate the irrigation schedules of tomato using CROPWAT computer model in Ataye.

MATERIALS AND METHODS

Description of the Study Area

The experiment was conducted at the Amhara region north Shewa Efratanagidim District a yimilo irrigation site. The site is located 154 km from Debreberehan town and 9 km from Ataye town. The geographic location of the experimental site is 39^0

1514 m.a.sl. The area has two major seasons; rainy and dry season. The rainy season lasts from the beginning of June to the end of September with mean annual rainfall of 822 mm, while the dry season lasts mainly from October to the end of May. The hottest months, February, April and May with mean monthly maximum temperature of 27.7°C, while the coldest months are November and December with mean minimum temperature of 11.5°C.

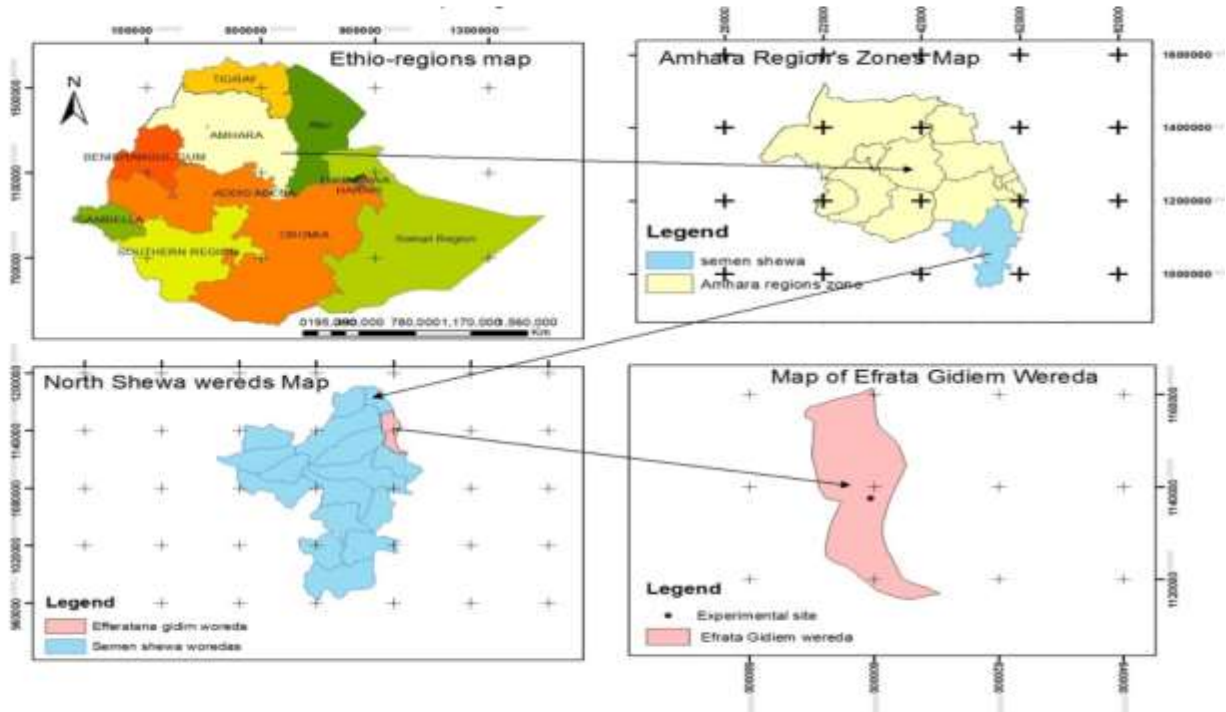

Figure 2. location map of experimental area

Field Layout and Experimental Design

The experiment was conducted in random complete block design with 15 treatments set up and 3 replications. The unit plot size was 2.1m * 4m ($8.4m^2$). Treatments were assigned to each experimental plot by using SAS Software to randomize within a replication. The space between plant, row, plot and replication is 30cm, 75cm, 1m and 2m respectively.

Table 1 Treatments and applied water levels

Treatments	Applied water level
T1	50% ETC
T2	75% ETC
T3	100% ETC
T4	125% ETC
T5	150% ETC
T6	50% ETC before 3-day interval
T7	75% ETC before 3-day interval
T8	100% ETC before 3-day interval
T9	125% ETC before 3-day interval
T10	150% ETC before 3-day interval
T11	50% ETC after 3-day interval
T12	75% ETC after 3-day interval
T13	100% ETC after 3-day interval
T14	125% ETC after 3-day interval
T15	150% ETC after 3-day interval

The reference evapor-transpiration value (ETo) for the site was calculated from the long-term meteorological variables (Monthly Minimum and Maximum temperature, wind speed, sunshine hours and relative humidity) using the cropwat version 8.0, based on the Pen man-Moeinth formula. The Kc values have been adopted from the FAO cropwat computer model. FAO cropwat computer model has finally been employed to obtain the crop water requirements of the crop and exercising irrigation scheduling for the site.

Experimental Field Management

conventional plowing practice (plowing was done twice before sowing the test tomato crop traditional plow called *Maresha*, drawn by a pair of oxen). Stubbles, weeds etc. were removed from the field. The experimental field was divided into three main blocks (Replicates) and each block was divided into fifteen plots which received different treatment combinations All agronomic practices were applied equally for each treatment according to the recommendation of the area (starting from sawing to harvesting recommended package of practices were followed). Disease, insect pest and weeding management were carried out as required.

Soil Sampling and Analysis

Soil samples were taken from experimental field at 0-20cm depth using an auger before sowing. The composite soil samples were prepared by quartering and air-drying at room temperature, ground using a pestle and a mortar and allow passing through a 2mm sieve. Working samples were obtained from bulk sample and was analyzed to determine the soil physico-chemical properties like, soil texture, organic matter, and soil pH, and CEC and bulk density.

Table 2 method to determine chemical and physical properties of soil

Parameters	Properties of the soil		method
	Chemical	Physical	
P^H EC OC OM Soil texture Bulk density			P^H meter or electrometer EC-meter or electrometer Walkley and black ,1934 1.724*OC, Broadbent, 1953 Hydrometer, Bouyoucous, 1962 Volumetric meter

Field Operations and yield harvesting

The tomato (Woino) variety was raised on a plot of land adjacent to the experiment plot for a period of thirty days in accordance with recommendation of Anonymous, (1976) before being transplanted. Recommendation rate of phosphorus, and nitrogen as a source of NPS and Urea fertilizer was applied at the rate of 240 Kg/ha and 100kg/ha respectively to the field.

Tomatoes harvested were estimated into marketable and non-marketable yields. Marketable yields were those crops harvested and transported to the market with market prevailing price. Non-marketable yields were those crops obtained from the experimental site as damaged tomatoes and/or those that could not be sold.

Water use Efficiency

According to Majumdar (2004), water use efficiency can be determined as the ratio of the amount of marketing yield crop yield to the amount of water required for growing the crops.

It can be calculated as; $Eu = \frac{Y}{WR}$

Where; Eu = field water use efficiency (t/ha-mm)

Y = crop yield (t/ha)

WR = Water requirement of the crop (ha-mm)

Data Collection and Measurements

The dada taken from the experimental site for analysis were growth parameters (plant height, fruit diameter and number of fruit), yield parameter (fruit yield) in both marketable and unmarketable yield amount of water and frequency (interval) during application period.

Data analysis

The collected data were subjected to analysis of variance (ANOVA) using SAS 9.0. Where ever the treatment effect was significant, mean separation were made using the least significance difference (LSD) test at 5% level of probability. Correlation analyses of selected parameters were also performed using Pearson correlation.

RESULTS AND DISCUSSION

Physico-chemical Properties of Soil before Planting

Some of the physicochemical properties of soils of the study sites before planting are summarized in Table 3. Accordingly, the soils of location belong to clay textural class based on soil textural class determination triangle of International Soil Science Society (ISSS) system (Rowell, 1994).

Table 3 Soil physical and chemical properties at Ataye

parameter	Value	parameter	Value
Sand (%)	28	OC	1.8
Clay (%)	38	OM (%)	3.04
Silt (%)	34	BD	1.37
pH	7.8	PW	23.4
EC (ds/mm)	0.23	FC	6.95

OC=organic carbon, OM=organic matter, BD=bulk density, PW =permanent wilting point, FC = field capacity EC =electric conductivity

Reference evapotranspiration of the experimental site

The simulated result of the metrological data for reference evaporation of the study site summarized with respect to each month and average ETO in table 4.how ever, using 10

Table 4 the reference evapotranspiration (ETo) values at Ataye

Month	Min Temp	Max Temp	Humidity	Wind	Radiation	ETo
	°C	°C	%	km/day	MJ/m²/day	mm/day
January	12.1	25.7	60	156	18.2	3.9
February	12.8	27	60	173	21.1	4.59
March	13.6	26.7	59	173	18.5	4.4
April	13.6	27.7	69	156	19.9	4.45
May	14	27.2	62	173	21.2	4.75
June	13.8	26.1	76	104	18.1	3.73
July	11.8	21.1	88	104	15	2.82
August	12	20.8	90	104	14.9	2.77
September	12.8	22.5	83	112	16.9	3.24
October	12.6	24.6	64	190	19.8	4.23
November	11.3	25	62	190	21.1	4.3
December	11.5	25.2	60	173	18.9	3.97
Average	12.7	25	69	150	18.6	3.93

As mentioned in table 2, the highest monthly ET0 for the site was observed in May (4.74 mm/day), while the lowest was detected was observed in August 2.65 mm/day. The result indicated that ETo was higher during the dry season and lower in the rainy season

The probable irrigation season for Ataye may start as early as November where the evapotranspiration rates are relatively low until the crops will have full maturity and hence planting during those periods will have two advantages; using the soil moisture reserve that could have been stored from that recedes in late September or early October. Secondly, planting crops at times of low evapotranspiration is implicated that the demand of the crops for water is also low. Therefore, irrigation water saving is more practical for early planning. To determine the amount of water needed and when to apply it, calculate the ETc (crop water use) between irrigations with the following equation, where Kc is the crop coefficient and ETo is the reference crop evapotranspiration: ETc = Kc x ETo**.** Doorenbos and Pruitt (1977) divided the kc curve into four stages: initial, crop development, mid and late-season stages. The Initial growth stage occurs from sowing to about 10% ground cover, the crop development stage from about 10% to70% ground cover. The Mid-season stage includes flowering and yield formation, while the Late-season includes ripening and harvesting.

Crops have different water requirements depending upon the place, climate, soil type, cultivation method, etc., and the total water required for crop growth is not equally distributed over its whole life span over its whole life span (Some, et al).

The trend of average crop evapotranspiration (ETc) and reference evapotranspiration (ET0) for tomato was illustrated for the whole growing season in Fig. (3). The ETc values were clearly less than ET0 in the early developmental stages, but the ETc increased with time due to canopy growth until it exceeded ET0 near the end of the crop season. Low ETc rate occurred during the first Days or the month of Jan, when only few leaves contributed to the evapotranspiration and most ETc was evaporation from the soil. Water consumption increased from Feb to Mar, mainly due to water use by the plants during the vegetative stage. Maximum water requirements occurred during the flowering stage or the month of April (mid stage) and water use decreased from last day April (fruit set stage). Daily ET crop varied from <2.41 mm/day at crop establishment to 2.92 mm/day at early vegetative growth and 4.33 mm/day at late vegetative growth and achieved a peak of 5.05 mm/day at flowering. ET crop then declined to a value of 4.35 mm/day during the ripening stage (late stage). The performance of the various depth of water applied were based on tomato yield.

Table 5 Crop water requirement for tomato

Month	Decade	Stage	Kc coeff	ETcrop mm/day	ETcrop mm/dec	Ir. Req. mm/day	Ir. Req. mm/dec
Jan	2	Init	0.6	2.34	11.7	2.34	11.7
Jan	3	Init	0.6	2.48	27.3	2.48	27.3
Feb	1	In/De	0.61	2.65	26.5	2.65	26.5
Feb	2	Dev.t	0.69	3.18	31.8	3.18	31.8
Feb	3	Dev.t	0.84	3.78	30.2	3.78	30.2
Mar	1	Dev.t	0.98	4.36	43.6	4.36	43.6
Mar	2	De/Mi	1.1	4.85	48.5	4.85	48.5
Mar	3	Mid	1.15	5.08	55.8	5.08	55.8
Apr	1	Mid	1.15	5.1	51	5.1	51
Apr	2	Mi/Lt	1.11	4.96	49.6	4.96	49.6
Apr	3	Late	1.01	4.6	46	4.6	46
May	1	Late	0.87	4.1	41	4.1	41
Totals					463	463	

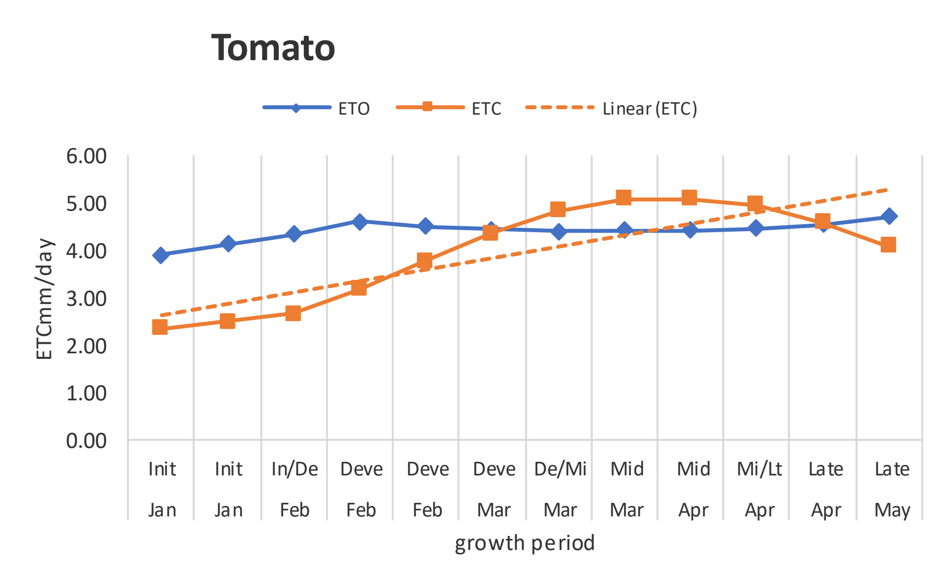

Figure 3 Temporal Crop evapotranspiration (ETc) and Reference crop Evapotranspiration (ET0) of Tomato

Tomato yield and yield parameter

The trend of PH ,NMF and NUMF growth yield parameter in first year and second year for tomato was illustrated for the application of different amount level of water depth in table (6).in first year the maximum values of PH,NMF and NUMF in the treatment of 125% ETc before 3-day interval, 125% ETc and 100% ETc before 3-day interval and the minimum values parameters 50% ETc before 3-day interval, 50% ETc after 3-day interval and 150% ETc before 3-day interval respectively. in the second year the maximum values of the parameters 125% ETc after 3-day interval, 50% ETc and 50% ETc and the minimum values also 75% ETc before 3-day interval, 150% ETc before 3-day interval and 50% ETc before 3-

day interval respectively the difference occurs due to the application level of water and the days of interval. But statistically shows that the analysis of variance of the tomato crop growth yield distribution for treatments, which indicated that there was highly significant

significance and there was no significant difference among number of marketable fruit at 5 % level of significance in first year while there was no significant difference among plant height, number of marketable fruit and number of unmarketable fruit at 5 % level of significance in second year.

Table 6. The response of plant height, number of marketable fruits, non marketable fruit, on the application of different amount of water in two years

	First year			second year		
Treatment	Ph cm	NMf /ha	NUMf /ha	Ph cm	NMf/ha	NUMf /ha
50% ETc	63^{fgh}	479369	96428.57	84.33	338892.9	47226.19
75% ETc	65^{efgh}	478179	99607.14	75.87	267059.5	35714.29
100% ETc	77^{ab}	537702	106345.2	80.27	194440.5	25000
125% ETc	70^{cdef}	525000	142857.1	89.2	244440.5	34916.67
150% ETc	62^{gh}	490083	95238.1	85.6	319047.6	36511.9
50% ETc before 3-day interval	60^{h}	448809	67464.29	85.47	233726.2	22226.19
75% ETc before 3-day interval	64^{efgh}	489678	99202.38	74.93	304369	41666.67
100% ETc before 3-day interval	76^{ab}	475797	130559.5	78.07	216666.7	26988.1
125% ETc before 3-day interval	82^{a}	494845	130321.4	84	196273.8	36904.76
150% ETc before 3-day interval	72^{bcd}	416512	74607.14	83.47	188571.4	28571.43
50% ETc after 3-day interval	74^{bcd}	399202	85714.29	85.2	278964.3	36107.14
75% Etc after 3-day interval	70^{cdef}	525000	85321.43	83.93	297619	36511.9
100% ETc after 3-day interval	67^{defg}	402143	109916.7	67.67	244845.2	39678.57
125% ETc after 3-day interval	65^{efgh}	473417	84607.14	95.2	311904.8	33726.19
150% ETc after 3-day interval	68^{defg}	473012	86904.76	76.07	263488.1	32535.71
CV (%)	5.41	10.55	17.51	16.1	30.34	28.6
Mean	69	473917	99673.01	81.95	260021.2	34285.71
LSD (0.05)	2.79	NS	10.96	NS	NS	NS

The response of MYF, UNMYF and TYF yield parameter and total application water application and water use efficiency for tomato was illustrated with the respect to each treatment in Table (7). The maximum values of MYF, UNMYF and TYF were in the

. And the minimum value of the yield parameters was in the

Statically the analysis of variance of the tomato crop yield distribution for treatments, which indicated that there was significant difference among the marketable yield, total yield and water productivity of crop at 5 % level of significance and there was no significant difference among total number of fruits, unmarketable fruit yield at 1% level of significance. The highest yield was 54.49 t/ha while the lowest was 37.89 t/ha. Statically 48.5 t/ha yield in the amount of irrigation water 376.71 mm depth with the water use efficiency 10.79 kg/m^3 safe 3127.33m^3 water from one hectare and get 0.59 ha additional irrigation land.

Table 7. The response of marketable fruit yield t/ha, unmarketable fruit yield t/ha, and total fruit yield on the Application of different amount of water

Treatment	MYF t/ha	UNMYF t/ha	TYF t/ha	WUE kg/m^3	TW m^3/ha
50% ETc	31.11^{f}	6.78	37.89^{e}	9.42^{bc}	3931.81
75% ETc	39.39^{bcde}	5.79	45.19^{bcde}	8.46^{cd}	5244.2
100% ETc	43.00^{abcd}	6.04	49.04^{abcd}	7.39^{de}	6546.25
125% ETc	47.62^{a}	6.88	54.49^{a}	7.24^{de}	7559.27
150% ETc	44.84^{ab}	6.69	51.53^{ab}	5.87^{e}	9227.11
50% ETc before 3-day interval	33.56^{f}	4.97	38.52^{e}	11.28^{a}	3389.96
75% ETc before 3-day interval	41.66^{abcde}	7.29	48.95^{abcd}	10.79^{ab}	4431.94
100% ETc before 3-day interval	38.65^{bcdef}	7.01	45.66^{bcde}	8.10^{cd}	5465.34
125% ETc before 3-day interval	39.00^{bcdef}	7.04	46.05^{abcde}	6.97^{de}	6505.11
150% ETc before 3-day interval	37.38^{bcdfe}	6.18	43.56^{de}	5.99^{e}	7460.39
50% ETc after 3-day interval	35.98^{cdf}	6.26	42.25^{de}	9.27^{bc}	4473.65
75%ETc after 3-day interval	42.78^{abcd}	6.50	49.29^{abcd}	8.52^{cd}	5641.17
100 ETc% after 3-day interval	39.36^{bcde}	7.06	46.42^{abcde}	6.31^{e}	7624.39
125% ETc after 3-day interval	43.57^{abc}	6.56	50.13^{abc}	5.73^{e}	9254.32
150% ETc after 3-day interval	35.20^{def}	6.06	41.26^{cde}	3.72^{f}	10970.1
CV (%)	15.37	26.58	14.14	17.79	
mean	39.44	6.43	45.87	7.68	
LSD (0.05)	2564.1	NS	2743	0.58	

The yield and land opportunity which got from saving water in the application of water through time interval illustrated in figure 4. The highest land and yield got from treatment six which saving 4169.31m^{3}of water and 0.81 ha additional irrigation land to get the 31.4 t/ha

Table 8. Correlation: number of marketable yield, number of unmarketable yield, marketable yield (Kg)/ha, unmarketable yield (Kg)/ha, total yield (Kg)/ha, water amount m3/ha

	NMY	NUMY	M Y (Kg)/ha	UNMY (Kg)/ha	TY (Kg)/ha	water amount m3/ha
NMY	1					
NUMY	0.809	1				
M Y (Kg)/ha	0.835	0.798	1			
UNMY (Kg)/ha	0.772	0.894	0.729	1		
TY (Kg)/ha	0.862	0.859	0.988	0.826	1	
water amountm3/h	0.489	0.509	0.562	0.511	0.578	1

CONCLUSIONS AND RECOMMENDATION

The crop yield increase with increase in depth of water applied up to an optimum value beyond which it tends to reduce crop yield in the experimental area which is predominantly clay loam in texture. Statistically the total depth of water during growth period of tomato at Ataye and the same agroecology was to get 48.95t/ha tomato yield gave an additional irrigation land without high yield penalty. The application of water in each stage were initial 33.64 mm with 5 days interval, development1 60.54 mm with 9 days interval, development-2 94.18 mm with 14 days interval, mid 94.18 mm with 14 days interval and late 94.18 mm with 14 days interval water application used. This research result could be verified for confirmation and it works should be carried out using different tomato variety and irrigation method.

REFERENCES

irrigation based on drought tolerance and root signalling in potatoes and tomatoes. Agricultural Water Management, v.98, p.403-413, 2010.

Kijne J (2010). Teaching irrigation science and water management: accepting professional diversity. Irrigat. Sci. 29(1):1-10.

Muchovej RM, Hanlon EA, McAvoy E, Ozores-Hampton M, Roka FM, (2008) Management of Soil and Water for Vegetable Production in Southwest Florida. Institute of Food and Agricultural Sciences.

Parry MAJ, Flexas J, Medrano H (2005). Prospects for crop production under drought: Research priorities and future directions. Ann. Appl. Biol. 147:211-226

Roth, G., Harris, G., Gillies, M., Montgomery, J., & Wigginton, D. (2014). Water-use efficiency and productivity trends in Australian irrigated cotton: a review. *Crop and Pasture Science*, *64*(12), 1033-1048

Rowell. 1994. Based on soil textural class determination triangle of International Soil Science Society (ISSS) system

Smith M (1991). CROPWAT; Manual and Guidelines. FAO of UN, Rome, Italy.

Some, L.; Dembele, Y.; Ouedraogo, M.; Some, B.M.; Kambire, F.L.; Sangare, S. Analysis of Crop Water Use and Soil Water Balance in Burkina Faso using CROPWAT; CEEPA DP36; University of Pretoria: Pretoria, South Africa, 2006

Surendran U, Sushanth CM, Mammen G, Joseph EJ (2014). Modeling the impacts of increase in temperature on irrigation water requirements in Palakkad district: A case study in humid tropical Kerala. J. Water Clim. Change 5(3):472-485.

Tesfaye (2008), socio-economical functioning and economic performance of rainfed farming system in Adami tulu jido kombolicha district,Ethiopia. Agro-ec program Norwegin university of life science.P.68

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