Ethiopian Journal of Water Science and Technology (EJWST)

Available online at: https://survey.amu.edu.et/ojs/index.php/EJWST

Vol. 4 , 2021, pages: 1~14 ISSN(Print): 2220-7643

The Effect of deficit irrigation on Onion yield and water use efficiency: Concerning moisture stress areas of Arba Minch, Southern Ethiopia

Gezimu Gelu[1], Markos Habtewold[2] and Abebaw Bergene[2]

[1,2]South Agricultural Research Institute, Arba Minch Agricultural Research Center, Department of Natural Resources Management, Irrigation and Drainage Program. P.O.Box:2228, Arba Minch, Ethiopia.
[*]Corresponding author email: gezimugelu64@gmail.com Mobile +251964407037

ABSTRACT

To cope with scarce water supply, deficit irrigation is an important tool to achieve the goal of reducing irrigation water use and increasing water use efficiency (WUE) under scarce water resources. This experiment was conducted for the last three years (2018-2020)in Chano Mille Kebelle near Arba Minch to examine the level of deficit irrigation which allows the maximum yield of onion, WUE and economic return without significantly reducing the yield of onion. Randomized Complete Block Design was used to run the experiment with four Replications. The experiment comprised different levels of deficit irrigation treatment: 100% of ETc, 85% of ETc, 75% of ETc and 50% of ETc. Analysis of variance showed that there was a significant difference among treatments in terms of marketable yield, total yield, and WUE in three consecutive years. 100% of ETc gave the maximum marketable and total yield and WUE which was followed by 85% of ETc. Additionally, the combined analysis of the mean showed that the highest marketable yield 24.97ton ha^{-1}and a total yield of 28.63 ton ha^{-1}was observed from100% of ETc and followed by 22.13 ton ha^{-1}of marketable yield and 26.86 ton ha^{-1}of total yield from 85% of Etc without significant variation. The highest combined WUE of 4.445kg m^{-3} resulted from 50% of ETc compared to the other levels of deficit irrigation (3.12 kg m^{-3}, 3.02 kg m^{-3}, 4.27 kg m^{-3}) from 100%, 85% and 70%, respectively. Given economic return, 100% of ETc yielded the highest net benefit of 208008 Birr/ha and followed by 198558 Birr/ha observed from 85% of ETc without significant economic return. The minimum (123858 Birr/ha gained from 50% of ETc. Based on these findings, 85% of ETc of deficit irrigation under moisture stress areas of Arba Minch should be applied to save water, and increase economic return and command area.

Keywords: Deficit irrigation, Evapotranspiration, Water use efficiency, Moisture stress.

1st received: 29 Apr 2020; received in revised form 15 May 2021; accepted 20 May 2021.

1. INTRODUCTION

In the semi-arid areas of Ethiopia, water is the most limiting factor for crop production. In these areas where the number and distribution of rainfall are not sufficient to sustain crop growth and development, another approach is to form use the rivers and underground water for irrigation. Satisfying crop water requirements, although it maximizes production from the land unit, does not necessarily maximize the return per unit volume of water (Oweis et al., 2000).

To quantify the level of deficit irrigation, it is necessary to define the full crop water requirements. Fortunately, Penmann (1948) developed the combination approach to calculate evapotranspiration. Research on crop water requirements has produced several reliable methods for computing them. At present, the Penman-Monteith equation (Monteith and Unsworth, 1990; Allen et al., 1998) is the established method for determining the evapotranspiration of the major herbaceous crops with sufficient precision for management purposes.

Under conditions of scarce water supply, the application of deficit irrigation could provide greater economic returns than maximizing yields per unit of water. Deficit irrigation has been considered worldwide as a way of maximizing water use efficiency (WUE) by eliminating irrigation that has little impact on yield (English, 1990). With deficit irrigation, the crop is exposed to a certain level of water stress either during a particular period or throughout the whole growing season (Kirda, 2000). Deficit irrigation scheduling practice is the technique of withholding, or reducing the amount of water applied per irrigation at some stages of the crop growth to save water, labour, and in some cases energy. This practice does lead to some degree of moisture stress on the crop and a reduction in crop yield (Smith and Munoz, 2002).

In the study area, the water scarcity is alarming from time to time but the food demand is increasing. Especially the vegetable crops need of people in the study area is highly increasing. Particularly onion crops. The studies on water stress levels for onion in Ethiopia and particularly in the study area are limited. In addition, studies on the economic return of applying deficit irrigation to onion crops and other vegetables are rather scarce. Hence, policymakers lack relevant research outputs to disseminate and publicize to the community. Besides, growers, researchers, and decision-makers don't have much knowledge about the water use efficiency of the onion crop in the study area. Consequently, this study was intended to identify the level of deficit irrigation which allows for achieving optimum onion yield, WUE, and economic analysis of deficit irrigation.

2. MATERIALS AND METHOD

2.1. Experimental site description

This experiment was conducted in Chano Mille situated at a longitude of 37°34’59’’N and latitude of 6°75’25” E within an elevation of 1192 meters above sea level.

2.2. Experimental design and treatments

The experiment was laid out in a randomized complete block design (RCBD) with four replications and levels of treatment. The treatment was conducted under the furrow irrigation method. All cultural practices were applied following the recommendation made for the study area. The amount of irrigation water applied at each irrigation event was measured using a three-inch Par shall flume. The treatments comprised 100% ETc, 85% ETc, 70% ETc, and 50%ETc.The experimental field was divided into 16 plots with a plot size of 4mX4m. Spacing between plot and replication was 1m. Spacing between row and plant was 40cmX10cm. The experimental plot was pre-irrigated one day before the transplanting of the onion seedling. Before the commencement of deficit irrigation, two to three common light irrigations were supplied to all plots to ensure better plant establishment.

2.3. Climate data

The climatic data of temperature (minimum and maximum), rainfall, relative humidity, and wind speed were used for crop reference and evapotranspiration determination. The climatic data were collected from the nearby meteorological station situated at Arba Minch. During the experiment the mean monthly minimum and maximum temperature ranged from 16.5 to 31.7 °C; relative humidity from 55 to 72 %; wind speed from 95 to 130 km/day, rainfall from 31 to 131 mm, and reference evapotranspiration (ET_o) from 4.2 to 5.22 mm/day.

2.4. Crop data

The maximum effective root zone depth of onion used was 0.6 m while the soil water depletion fraction (P) allowed for this experimental study was 0.25. (Andreas *et al*., 2002). The crop coefficient used for initial crop development, mid, and late-stage was 0.7, 1.05, and 0.95, respectively.

2.5. Soil data

The soil data of the experimental site was sampled by the zigzag method across the experimental land. To characterize soils of the study site, soil physical and chemical parameters were determined in the field and laboratory. The laboratory analysis of soil showed that the average composition of sand, silt, and clay was 13%, 21%, and 66%, respectively. Thus, the particle size determination for the experimental site revealed that the soil texture could be classified as clay soil according to the USDA soil textural classification. The topsoil surface had a bulk density of 1.32 g/cm^3). When the average soil bulk density (1.32g/cm^3) is below the critical threshold level (1.4 g/cm^3), it is thought to be suitable for crop root growth.

The average moisture content of the experimental site soil at field capacity was 27% and the permanent wilting point was 15% through one-meter soil depth. Soil p^H was found to be at the optimum value (6.4) for onion and other crops. The value of EC (1.12ds) was lower according to the standard rates specified by Landon (1991). Generally, soil with electrical conductivity of less than 2.0 dS/m at 25°C and p^H less than 8.5 is considered a normal soil according to USDA soil classification. Therefore, the soil of the study area was normal. The weighted average organic matter content of the soil was about 7.085%. The infiltration capacity of the soil was measured by using a double ring inflitrometer and the infiltration rate was 6mm/hour.

2.6. Determination of reference crop evapotranspiration (ET_o)

The reference evapotranspiration (ETo) was determined by CROPWAT -8 model based on the Penman-Monteith model. ETo will be determined by using daily climatic data like relative humidity, temperature: maximum and minimum), wind speed and sunshine hours). The ET_o was calculated using equation (1) FAO (1998).

$$ETo = \frac{0.408\Delta(Rn-G) + \gamma \frac{900}{T+273} u2(es-ea)}{\Delta + \gamma\,(1+0.34u2)} \quad (1)$$

Where, ET_o is reference evapotranspiration [mm hour^{-1}]; Rn is net radiation at the grass surface [MJ m-2 hour^{-1}]; G is soil heat flux density [MJ m^{-2} hour^{-1}]; T is mean hourly air temperature [°C];

Δ is saturation slope vapour pressure curve at Thr [kPa °C^{-1}]; γ is psychometric constant [kPa °C^{-1}]; *es* is saturation vapour pressure [kPa]; *ea* is average hourly actual vapour pressure [kPa] and u2 is average hourly wind speed [m s^{-1}].

2.7. Crop water determination

Crop water requirement refers to the amount of water that needs to be supplied, while crop evapotranspiration refers to the amount of water that is lost through evapotranspiration (Allen *et al*., 1998). To determine crop water requirement, it is important to consider the effect of crop coefficient (Kc) and the effect of climate on crop water requirement, which is the reference crop evapotranspiration (ETo) (Doorenbos and Pruitt, 1977). The daily climate data like maximum and minimum air temperature, relative humidity, wind speed, sunshine hour and rainfall data of the study area were collected to determine reference evapotranspiration. Crop data like crop coefficient, growing season and development stage, effective root depth, and critical depletion factor of onion were also used as input data. Maximum infiltration rate and total available water of the soil were determined to calculate crop water requirement.

Crop water requirement was determined by using the equation (2)

$$ETc = ETo \times Kc \tag{2}$$

Where ETc is evapotranspiration; Kc is crop coefficient, and ETo is reference evapotranspiration. The mean monthly ETo for three consecutive years is shown in Table 1.

Table 1: Mean Monthly ETo of the study site

Month	ETo (mm/day)
January	4.38
February	4.75
March	5.22
April	4.7
May	4.2
June	3.89
July	3.55
August	3.9
September	4.07
October	4.25
November	4.1
December	4.11
Average	4.26

2.8. Irrigation water management

The total available water (TAW), stored in a unit volume of soil was determined by applying equation (3)

$$TAW = \frac{(FC-PWP)}{100} * BD * D \quad (3)$$

Where FC is the field capacity; PW is the permanent wilting point; BD is bulk density; D is the root depth. For onion production, the irrigation schedule was fixed based on readily available soil water (RAW). The RAW could be computed by using the equation (4).

$$RAW = PX\ TAW \quad (4)$$

Where RAW(mm) is readily available water, P(%) is permissible soil moisture depletion for no stress and TAW(mm) is total available water. The depth of irrigation supplied at any time can be obtained by using the equation (5).

$$\text{Net irrigation(mm)} = \text{ETc(mm)} - \text{Peff(mm)} \quad (5)$$

Gross irrigation requirement(GIR) was obtained by using equation (6) as:

$$GIR = \frac{\text{Net irrigation}}{\text{Ea}} \quad (6)$$

The time required to deliver the desired depth of water into each furrow was calculated by using equation (7):

$$t = \frac{d*l*w}{6*\ Q} \quad (7)$$

Where:d is the gross depth of water applied (cm;t is application time (min); l is furrow length in (m);w is furrow spacing in (m), and Q is the flow rate (discharge) (l/s). The amount of irrigation water to be applied at each irrigation application was measured by using Par shall flume.

2.9. Measurement of agronomic data

The amount of water applied per each irrigation event was measured by using a three-inch par shall flume. During harvesting time, the yield of onion was measured by using spring balance on a plot basis and the total yield of onion was measured by summing both marketable and un-marketable yields of onion. Un-marketable yield is onion bulb yield which is attacked by worms and other vectors and whose diameter is below 5mm.

Water use efficiency(WUE, kg m^{-3}) was determined by using equation 8:

$$WUE=\frac{\text{Onion yield}}{\text{evapotranspiration of onion}} \quad (8)$$

3. ECONOMIC ANALYSIS

It was carried out to compare the effects of water application and other inputs costs and return to the producers among different treatments. Economic analysis was employed as suggested by CIMMTY (1988) to determine water application levels based on cost and benefits and recommend feasible treatments. The following economic analysis indices were used to examine the feasibility of applying deficit irrigation treatment.

Gross average yield (kg ha^{-1}) (AvY): is the average yield of each treatment.

Adjusted yield (AjY): is the average yield adjusted downward by 10% to reflect the difference between the experimental yield and the yield of farmers.

$AjY = AvY–(AvY*0.1)$

Gross field benefit (GFB): was computed by multiplying the farm gate price that farmers receive for the yield when they sell it as adjusted yield GFB = AjY*farm gate price for haricot bean yield.

Total cost (TC) includes the costs of all inputs, such as haricot bean seed, fertilizer, insecticides, and labour. For economic analysis, the total cost can be put into two groups: fixed costs (FC) and variable costs (VC). The total cost is the summation of the fixed (FC) and variable (VC) costs (equation 9).

$$TC = FC + VC \quad (9)$$

The fixed costs (FC) do not vary among the technologies; it includes the cost of land, water tax and fertilizer whereas the variable costs (VC) do vary among the treatments. The variable costs (VC) include labourer wages.

Net benefit (NB): is the amount of money which is left when the total costs (TC) are subtracted from the Gross Field Benefit (GFB). It may be given as:

$$NB = GFB-TC \quad (10)$$

3.1. Statistical Analysis

Data analysis was carried out to compare the treatment effect on yield and water use efficiency of onion. The data collected for all relevant variables were subject to analysis of variance (ANOVA) which is appropriate for Randomized complete Block Design (RCBD) (Gomez and Gomez, 1984). The combined analysis of variance across years was conducted by using the analysis for statistics (SAS) software version 9.1 to determine the differences among treatments.. A comparison of means was carried out by employing the least significant differences (LSDs) (Gomez and Gomez, 1984) at 5% levels of significance.

4. RESULTS AND DISCUSSION

4.1. Marketable and Total Yield Response to Deficit Irrigation

Analysis of variance (ANOVA) showed that the application of deficit irrigation has significantly affected the marketable and total yield of onion over three consecutive years as shown in Table 2 at (p=0.05)

Mean values of three consecutive years applying 100% of Etc resulted in maximum yield and total yield of onion without significant variation with 85% of ETc whereas the minimum means were observed in onions with 50% of Etc. . The maximum marketable yield over three years obtained from 100% was 23.93ton ha^{-1}, 26.70 ton ha^{-1} and 27.13 ton ha^{-1} in the first, second, and the third year, respectively. The minimum marketable yield observed over three years from 50% was 15.17ton ha^{-1}, 14.34ton ha^{-1} and 13. 77 ton ha^{-1} in, the second, and third year, respectively. The maximum total yield observed over three years from 100% was 28.852 ton ha^{-1}, 26.70 ton ha^{-1} and 27.93 ton ha^{-1} in the first, second, and third years, respectively. The minimum total yield observed over three years from 50% was 20.981ton ha^{-1}, 18.175ton $ha^{-1}$and 14.4 ton ha^{-1} for the first, second and third years, respectively.

Combined means of marketable yield and total yield using ANOVA showed a significant variation among treatments of deficit irrigation at p=0.05. The maximum combined marketable yield (24.97 ton ha^{-1}) was observed from 100% Etc without significant variation with a mean yield of 22.13 ton ha^{-1} from 85% of ETc whereas the minimum yield of 20.39 ton ha^{-1}. The maximum combined total yield of 28.63 ton $ha^{-1}$was observed from 100% ETc without significant variation with 26.86 tons

$ha^{-1}$from 85% of Etc whereas the minimum total yield, of 3.015 ton ha^{-1} was observed from 50% ETc.

Generally, the reason behind the high performance of marketable yield, total yield, and combined mean under 100% of Etc might be due to the sufficiency of soil moisture in the active root zone. At the same time, lower performance under 50% of ETc was due to insufficiency of moisture in the root zone to satisfy the onion water demand during the growth stages of onion. Applying a high level of deficit irrigation significantly affected the metabolic reaction of onion which, in turn, affected the onion yield.

Table 2: Mean average yield and combine mean over three years

Treatment	Year 1		Year 2		Year 3		Combined mean	
	Y	TY	Y	Ty	Y	Ty	Y	Ty
100 % ETc	23.93[a]	28.852[a]	26.70[a]	28.70[a]	27.13[a]	27.93[a]	24.97[ab]	28.63[a]
85% ETc	22.09[a]	28.6319[a]	25.65[ab]	26.325[ab]	25.49[a]	25.97[a]	22.13[ab]	26.86[ab]
70 % ETc	18.78[ab]	24.6986[ab]	19.85[bc]	21.025[b]	21.14[b]	22.15[b]	21.34[b]	25.3b[c]
50%ETc	15.17[b]	20.981[b]	14.34[b]	18.175[c]	13.77 [c]	14.395[c]	20.39[c]	23.015[c]
CV	22.9	24.4	13.4	12.4	7	5	14.1	22.1
LSD(p=0.05)	3.779	4.132	4.81	10.525	1.764	1.764	3.7	4.7

Y= Marketable yield and Ty= total yield of onion

4.2. Water Use Efficiency of Onion

Analysis of variance (ANOVA) showed that the application of deficit irrigation has significantly affected the water use efficiency of onions as shown in Table 3 at p=0.05. From mean values of three consecutive years, applying 50% of Etc gave maximum mean water use efficiency (WUE) whereas the minimum mean of WUE was observed from 100% of ETc. Without significant variation with applying 85% of Etc, the maximum mean WUE observed from 50% of Etc was 6.7

kg m^{-3}, 7.939 kg m^{-3} and 6.149 kg m^{-3}in the first, second, and third years, respectively.. Without significant of applying 85% of ETc, the minimum mean WUE observed from 100% of Etc was 5.098 kg m^{-3}, 6.108 kg m^{-3} and 6.056 kg m^{-3}in the first, second, and third years, respectively. The maximum combined mean of WUE of (4.445 kg m^{-3}) was observed from 50% of ETc whereas the minimum (3.12 kg m^{-3}) WUE was observed from 100% of ETc without significantly varying 85% of ETc. The growers should select optimum WUE with optimum marketable yield and total marketable yield. From the statistical analysis, 85% of ETc gave optimum yield without significantly varying 100% of Etc. Applying 85% of Etc saved about 15% of the water that might increase the command area in a water-scarce area.

Table 3: Average and combined mean of water use efficiency (WUE, kg m^{-3})

Treatment	Year-1	Year-2	Year-3	Combined mean
100 Etc	5.098^{b}	6.108^{b}	6.056^{b}	3.12^{8c}
85% Etc	6.021^{ab}	6.904^{ab}	6.694^{a}	$3. 02^{b}$
70 % Etc	5.684^{ab}	6.488^{ab}	6.293^{ab}	4.272^{a}
50% ETC	6.700^{a}	7.939^{a}	6.149^{ab}	4.445^{ab}
CV	24.3	12.2	5	19.4
LSD	1.177	1.342	0.503	1.385

4.3. Onion water requirement determination

The water requirement of the onion crop for the specific site was calculated by using input data on climate and crop characteristics. Thus, based on the treatment set-up and crop water requirement, the amount of net irrigation was estimated and applied for each treatment. The amount of net irrigation requirement applied for 100% of ETc, 85% of ETc, 70% of Etc, and 50% of Etc was presented in Table 4. Table 4 also shows the application time for each treatment in different stages. It also shows the irrigation interval at which irrigation is applied and the average amount of net irrigation applied to the onion root zone.

Table 4: Irrigation scheduling for the response of onion to deficit irrigation

Days	100% of ETC		T -1		T -2		T-3		T -4	
	NIR	GIR	T1 (100% (ETc) NIR	Time (t1)	T2(85% (ETc) NIR	Time (t2)	T3 (70% ETc) NIR	Time (t3)	T4 (50% ETC) GIR	Time (t4)
10-Dec	21.1	35.2	21.1	15	17.9	12	14.77	7.3	17.6	7
16-Dec	12.9	21.5	12.9	9	11.0	8	9.03	4.4	10.75	4
22-Dec	13.9	23.1	13.9	10	11.8	8	9.73	4.8	11.55	5
26-Dec	17.8	29.7	17.8	12	15.1	11	12.46	6.1	14.85	6
2-Nov	12.2	20.4	12.2	9	10.4	7	8.54	4.2	10.2	4
6-Nov	13.6	22.6	13.6	9	11.6	8	9.52	4.7	11.3	5
10-Nov	14.9	24.9	14.9	10	12.7	9	10.43	5.1	12.45	5
14-Nov	14.9	24.9	14.9	10	12.7	9	10.43	5.1	12.45	5
18-Nov	10	16.7	10	7	8.5	6	7	3.4	8.35	3
22-Nov	10	16.7	10	7	8.5	6	7	3.4	8.35	3
26-Nov	19	31.6	19	13	16.2	11	13.3	6.5	15.8	7
30-Nov	19.9	33.2	19.9	14	16.9	12	13.93	6.9	16.6	7
3-Jan	19.9	33.2	19.9	14	16.9	12	13.93	6.9	16.6	7
7-Jan	12.7	21.2	12.7	9	10.8	8	8.89	4.4	10.6	4
11-Jan	13	21.6	13	9	11.1	8	9.1	4.5	10.8	5
15-Jan	20.8	34.7	20.8	14	17.7	12	14.56	7.2	17.35	7
19-Jan	15.3	25.4	15.3	11	13.0	9	10.71	5.3	12.7	5
23-Jan	15.3	25.4	15.3	11	13.0	9	10.71	5.3	12.7	5
27-Jan	11.8	19.7	11.8	8	10.0	7	8.26	4.1	9.85	4
1-Feb	11.6	19.4	11.6	8	9.9	7	8.12	4.0	9.7	4
5-Feb	19.4	32.4	19.4	14	16.5	11	13.58	6.7	16.2	7
9-Feb	14.2	23.6	14.2	10	12.1	8	9.94	4.9	11.8	5
13-Feb	14.2	23.6	14.2	10	12.1	8	9.94	4.9	11.8	5
19-Feb	10.1	16.9	10.1	7	8.6	6	7.07	3.5	8.45	4
25-Feb	18.8	31.3	18.8	13	16.0	11	13.16	6.5	15.65	7
31-feb	16.4	27.3	16.4	11	13.9	10	11.48	5.7	13.65	6
6-Feb	19.9	33.2	19.9	14	13.9	28.2	13.93	6.9	10	6
12-Mar	14	23.3	14	10	16.9	19.8	9.8	4.8	7	6
18-Mar	20.4	33.9	20.4	14	11.9	28.82	14.28	7.0	10	6

GIR, Gross irrigation requirement, NIR, net irrigation requirement T1, T2, T3, T4, time required to irrigate each treatment, T-1, T-2 T-3 etc., and Treatment.

4.4. Economic analysis

For treatments, the economic return was calculated using CIMMYT (1988) standards and was summarized in Table 4 below. In Table 4, the highest net benefit of 208008 Birr/ha was recorded from 100% ETc which was followed by 19855 Birr/ha) recorded from 85% of ETc through the growing season. The lowest value of economic return or gross income of 23858 Birr/ha was obtained from 50% of ETc. Regarding economic return, 100% of ETc is better than other levels of deficit irrigation. However, there is no significant difference in economic benefit, water use efficiency, and yield with 85% of ETc. Based on the findings of the current study, it is better to apply 85% of ETc because it saves about 15% of water when compared to 100% ETc.

Table 4: Economic analysis of deficit irrigation

SN	Treatment	MY(kg/ha)	AY(kg/ha	GFB (birr/ha)	FC(Birr/ha)	VC(Birr/ha)	TC(Birr/ha)	NB(Birr/ha
1	100% ETc	26700	24030	240300	15292	17000	32292	208008
2	85% ETc	25650	23085	230850	15292	17000	32292	198558
3	70% ETc	19850	17865	178650	15292	17000	32292	146358
4	50% ETc	17350	15615	156150	15292	17000	32292	123858

MY- marketable yield, AY, adjusted yield (-10% of MY), GFB-gross field benefit, FC- fixed cost, VC-variable cost T C – total cost NB – net income and ET Birr, Ethiopian Birr.(1 USD dollar=45 Ethiopian birr)

5. CONCLUSION AND RECOMMENDATION

The onion yield decreases with increasing deficit level of irrigation. The maximum marketable onion yield was obtained from 100% of Etc without significant difference with 85% of ETc. Based on the current study, applying 85% of ETc saves water that can increase command area, WUE, and economic benefit. Economic analysis also showed that applying 100% of ETc would give maximum net benefit without significantly varying from applying 85% ETc. Based on economic analysis, applying 85% ETc is economically viable for smallholder farmers in a moisture stress area. So, it is recommended to produce onion at a deficit level of 85 % of ETc in the case of Arba Minch and similar agro-ecologies to produce optimum onion yield and increase command area. As a future research direction, it is recommended to experiment on different levels of deficit irrigation with appropriate irrigation scheduling techniques and soil moisture monitoring to improve WUE and land productivity.

Acknowledgements

The authors thank Arbaminch Agricultural Research Center and Southern Agricultural Research Institute for allocating the budget for researchers, drivers, and wages for daily workers; facilitating the use of natural resources and logistic provision.

REFERENCES

Allen, R. Pereira, L.A. Raes, .D Simth, M.,(1998): Crop Evapotranspiration Guidelines for Computing Crop Water Requirement. FAO Irrigation and Drainage Paper Number 56, FAO, Rome.

Andreas, P. and F. Karen., (2002): Crop Water Requirements and Irrigation scheduling. Irrigation Manual Module 4.Harare.P.86.

Brady, N.C., and R.R. Weil,(2002): The nature and Properties of Soils.13th ed. Perso education Ltd., USA.

CSA (Central Statistical Authority (2007): Area and Production of Major Crops. Sample Enumeration Survey. Addis Ababa, Ethiopia.

Doorenbos, J. and Kassam, A. H. (1979): Yield Response to Water. Irrigation and Drain. Paper No. 33, FAO, Rome, Italy. 193 p.

Doorenbos, J. and W.O. Pruitt.,(1977): Guidelines for predicting crop water requirements. FAO Irrig. Drain. Paper No. 24.FAO, Rome, Italy. 179 p.

English MJ,(1990): Deficit irrigation. Analytical framework. *Journal of American Society of Civil Eng116: 399-412*.

Fereres, E., and Soriano, M.A.(2007): Deficit irrigation for reducing agricultural water use. *Journal Experimental Botany* 58 (2):147–159.

Kirda C. (2000): Deficit irrigation scheduling based on plant growth stages showing water stress tolerance. Deficit Irrigation Practices.

Littell, R.C., G.A. Milliken, W.W. Stroup, R.D. Wolfinger, and O Schabenberberet.(2006): SAS for Mixed Models, 2nd Ed. SAS Publishing, Cary, NC.

Mahbub.H, Tamara.C, Mebougna.D, A.K,C. G,(2015): Modeling of Infiltration Characteristics by Modified Kostiakov Method. http://www.scirp.org/journal/jwarp, http://dx.doi.org/1 .4 236/jwarp.2015.716106

Oweis, T. Zhang, H and Pala, M. (2000). Water use efficiency of rainfed and irrigated bread wheat in a Mediterranean environment. *Agronomy Journal* 92: 231-238

Peirce, L.C.,(1987): Vegetables characteristics, production and marketing.John Wiley and Sons.Inc. Toronto. Canada

Purseglove, R..(1988):Tropical Crops Dicotyledons. Fifth edition. Longman Publisher Singapore

Shankara.N.,J.Lidetde, M.Goffau, M.Hilmi and B.VanDam(2005):Cultivation of Tomato Production, Processing and Marketing.

Smith M, Munoz G (2002): Irrigation Advisory Services for EffectiveWater Use: A Review of Experience. Irrigation Advisory Services and Participatory Extension in Irrigation Management Workshop Organized by FAO-ICID. Montreal, Canada.

Staney,W.C. and Yerima, B.(1992): Improvement of soil services for agricultural development: guidelines for soil sampling and fertility evaluation, Ministry of Natural Resources Development and Environmental Protection, Addis Ababa, Ethiopia.

Walker, W. R.,(2003): Guidlines for Designing and Evaluating Surface Irrigation Systems. FAO Irrigation and Drainage Paper 45 FAO, Rome.