Etissa et al., Irrigat Drainage Sys Eng 2016, 5:2
DOI: 10.4172/2168-9768.1000167

Irrigation & Drainage Systems Engineering

Research Article Open Access

Estimation of Yield Response (Ky) and Validation of CropWat for Tomato under Different Irrigation Regimes

Etissa E[1]*, Dechassa N[2] and Alemayehu Y[2]

[1]*Ethiopian Agriculture Research Organization, Addis Ababa, Ethiopia*
[2]*Haramaya University, Ethiopia*

Abstract

Field experiment was conducted at Melkassa Agricultural Research Center with the objectives to determine the optimal irrigation levels for maximum tomato production and to assess the effect of limited water supply on field grown tomato yield and to estimate 'yield response of tomato to soil water (Ky)' and to validate CropWat irrigation model using the data for tomato cultivation during hot-dry season conditions. Three irrigation scheduling levels such as 1) 100% of crop water requirement (ETc) (Full irrigation) 2) 80% ETc (Full) (= 0.80 ETc) and finally 3) 60% ETc (= 0.60 ETc) were used using drip irrigation replicated three times; the tomato was subjected to various levels of water stresses over whole growth period. Yield data such as marketable, unmarketable and total fruit yield were collected at each harvesting and summed at the end of harvesting. The results of data analysis showed that use of various irrigation depth brought a significant effect (P<0.01) effect on the marketable yield of tomato whereas application of various irrigation depths did not bring significant difference (P<0.05) on unmarketable fruit yield of tomato. Use of various irrigation depths had a significant effect (P<0.05) on the total fruit yield of tomato. The mean separation indicated that the highest fresh fruit yield was obtained from full irrigation and the lowest was obtained from 60% irrigation. Thus, the total fresh fruit yield obtained from fully irrigated tomato plot exceeded the fresh fruit yield obtained from tomato plot irrigated with only 60% of full irrigation water by 62.8%. The results showed that with decrease in the depth of irrigation, there was a decrease in total fruit yield in tomato due to reduced uptake of water. The yield response (Ky) of tomato throughout the crop cycle was calculated and found to be 0.999, indicating that the yield reduction is directly proportional to reduced water use. Then the CropWat irrigation model was validated using field data for tomato cultivation. Accordingly, the efficiency of the model was found to be 94%, indicating that the model is a useful decision support system to help tomato growers.

Keywords: CropWat; EToCal; Irrigation regime; Simulations; Yield response

Introduction

The Central Rift Valley (CRV) area of Ethiopia is amongst the pioneers of market-oriented irrigated vegetable crops production in Ethiopia. Using various water sources for irrigation; vegetable production in this area has nowadays expanded where most growers use hybrid seeds and considerable agricultural inputs.

Agriculture in this area is dominated by traditional small scale irrigation at household level with very small farm size [1,2]. Thus, improving small scale irrigated vegetable production system is expected to improve livelihoods and sustain the environment. Demeke and Haile found that vegetable crops growers that have access to small scale irrigation has an important impact on poverty reduction through high income, and improved wellbeing of farming households.

In all parts of Ethiopia, tomato is produced under furrow irrigation in open field. Based on survey conducted by Etissa et al. [2] among the vegetable grower using furrow irrigation, 16.48% replied that the knowledge source of their irrigation management packages was from experience, while 12.08% replied that the knowledge source was obtained from experience and family and all the remaining replied different sources; the survey indicated that vegetable growers got knowledge and practices from variety of sources showing furrow irrigation is totally is not technical and scientific based. Small holder farmers did not indicate that their irrigation scheduling is supported by improved irrigation technologies in the country.

In addition, because of profitability of vegetable crops production using irrigation on one hand and the current low production and productivity of existing vegetable crops and farm lands in the study area on the other hand, 86.31% of growers responded that they have interests in increasing their irrigable farm land area to expand and intensify vegetable production [1,2]. However, due to the expansion of irrigated areas and uncontrolled irrigation water in the upstream of Central Rift Valley, all the downstream of middle and lower Awash Basin, there is not only limited availability of irrigation water, but also critical water shortage, there is a need for optimal irrigation management and scheduling in order to maximize crop yields under water deficit conditions so that efficient use of water for agriculture is increased.

Among irrigation systems, many losses encounter surface and furrow irrigation, like conveyance loss, surface run off, deep percolation etc... From very limited water sources compared to crop water requirements. It is economically necessary to get even more from the water: this may be done in many cases by adopting efficient irrigation methods through improved efficiency, which can apply the scarce water more accurately; minimizing losses through different ways. The water then can be used much more efficiently for supplemental irrigation for much larger areas, or for longer seasons. The experience from many countries show that farmers who changed from furrow system to drip systems can cut their water use by 30% to 60% and crop yields often increase at the same time [3]. The use of drip irrigation system permits reduction of water losses up to 50%. Hochmuth and Hanlon [4] and can increase the yield per unit of land by up to 100% compared with surface irrigation systems [5].

***Corresponding author:** Etissa E, Ethiopian Agriculture Research Organization, Addis Ababa, Ethiopia, E-mail: edossa.etissa@gmail.com

Received June 07, 2016; **Accepted** July 12, 2016; **Published** July 19, 2016

Citation: Etissa E, Dechassa N, Alemayehu Y (2016) Estimation of Yield Response (Ky) and Validation of CropWat for Tomato under Different Irrigation Regimes . Irrigat Drainage Sys Eng 5: 167. doi:10.4172/2168-9768.1000167

In several places in Ethiopia, there are extensive campaigns of water harvesting, tapping ground water and using appropriate technologies like treadle pump, rope and washer pumps with the realization that in many places existing water resources cannot meet the needs of the expanding population. Hence, it is very crucial to assess effect of irrigation levels for maximum tomato production and to assess the effect of limited water supply on tomato growth and yield. The objectives of this study are to determine the optimal irrigation levels for tomato production and to assess the effect of limited water supply on tomato yield; to estimate 'yield response of tomato to soil water (*Ky*)' and finally to validate CropWat irrigation model using the data for tomato cultivation for Melkassa during hot- dry season.

Materials and Methods

The experiment was conducted at Melkassa Agricultural Research Centre during the hot- and dry season. There was no rainfall since tomato planting to final harvesting during the experimental period. The detail of materials and methods were published in African Journal of Agricultural Research, by Edossa et al. [6].

Treatment arrangement, experimental materials and procedures

Treatment arrangement: Irrigation scheduling treatments include 1) 100% of crop water requirement (ETc) (Full irrigation), 2) 80% ETc (Full) (=0.80 ETc), 3) 60% ETc (=0.60 ETc). *'Melkasholla'* semi-determinate tomato variety was subjected to various levels of irrigation levels (water stresses) over whole growth period. The plots were replicated three times.

Experimental procedures: *Melkasholla* tomato variety was used for field experiment; it is a multipurpose variety released from Melkassa ARC; it is semi-determinate growth habit. The detail of the procedures was published by Edossa et al. [6]. Tomato seeds were sown in a nursery in a row with the row spacing of 10 cm with very dense spacing within rows. The size of the seedbed was 5 m length and 1 m width. The seed was drilled onto the seedbeds and covered with a soil layer of 1/5 cm. 100 g Urea and 200 g DAP were applied per bed and thoroughly mixed with the soil as recommended by Lemma. Watering was done in the interval of three days throughout the growth period of the seedlings in the nursery for both experiments. Field preparation consisted of ploughing by a mould board plough into the depth of 40–50 cm deep followed by 10 to 15 cm deeper thorough operation of disc harrowing before ridging. Plots with the individual size of 7.0 × 4.5 m, total of 31.5 m^2, with seven rows, and each row accommodating 15 plants was marked out. The spacing between rows was 100 cm and 30 cm between plants. A total of 61 plants and 44 boarder plants were transplanted. Seedlings were transplanted to the permanent experimental field as recommended by researchers. Pre-plant irrigation was applied, since past rainfall was insufficient to replenish the soil profile [7]. Seedlings were transplanted in field at the usual spacing. A total of 60 experimental plants were planted within each plot and before initiating treatments, plants (seedlings after transplant) were irrigated to nearly field capacity for three weeks in order to improve root development [8].

Irrigation system descriptions:

Low-cost gravitational drip structures and installations: The low-cost gravitational surface drip structure used for the experiment comprised water source tanker at the elevated position, filter, water tank connector, straight connector, connector, control valve, main line, lateral pipe, emitter, wood and nail for tanker stand. Four tankers having the capacity of 2000 litres each were placed at the irrigation regime at the head of strip plot. The tankers were placed in the field at the height of 1.0 m from above the ground so that water would be at the height necessary to provide the water pressure required operating the system. Once the seedlings were well established for 20 days, the irrigation treatments were commenced.

Each plot consisted of lateral drip lines with 5.5 m length. The emitters on laterals were spaced at 0.3 m corresponding distance of tomato plant spacing within a row in the field. The lateral line was laid out along each tomato row. Each tomato plants were planted under emitter so that they would benefit from the water supplied by the emitters. The field was furrow-irrigated before planting and after transplanting for ten days for crop establishment before imposing drought stress treatments.

Three and half meter distance buffer zone separate each plots or side flows were precluded to avoid lateral run-on and run-off (side flows) from other irrigation treatment plots.

Methods for estimation of soil water

Estimation of daily crop water requirement: The initial soil water content for top soil at the time of transplanting is assumed to be close to field capacity as a result of continuous pre-irrigation. This assumption is dictated by the fact that small vegetable seedlings are extremely very sensitive to moisture stress. Then the proper amount of daily irrigation for a crop is the amount of daily ET taking place minus any daily effective rain fall [9].

Application of daily time step irrigation scheduling: Equal amount of irrigation water were applied to each treatment before the initiation of irrigation treatments (sum of daily ETc). Once the drip system was installed, the drip irrigation was done on the basis of ETo [10] value of the previous day. The amount of irrigation water applied, ETm, was determined from the calculated water requirement for tomato as determined from the crop coefficient (Kc) and the daily reference evapotranspiration (ETo) using the following equation:

$$ETc = ETo * Kc$$

Irrigation scheduling was based on a check book of soil water balance budget method (ETc=ETo*Kc) where simple accounting approach is used for estimating how much soil-water remains in the effective root zone based on water inputs and outputs. Irrigation was scheduled when the soil-water content in the effective root zone was near the predetermined allowable depletion volume through keeping track of rainfall, evapotranspiration, and irrigation amounts. Irrigation treatments were applied once a day until the required volume of water was completely gone from the tanker. The total amount of irrigation water applied to each treatment was calculated as the sum of water applied during the crop establishment period and the ETc of the remaining period.

Daily reference ETo: The daily ETo data were calculated with the software programme EToCalc developed by Raes [11] on basis of the FAO Penman Monteith equation from Melkassa Weather Station [10].

Net irrigation (IR_n): It is the amount of irrigation water required to bring the soil moisture level in the effective root zone to field capacity [12].

$$IR_n = ETc - P_e + LR \text{ (mm)}$$

Where,

IR_n=Net irrigation requirement (mm)

ETc=Crop evapotranspiration (mm)

P_{ef}=Effective dependable rainfall (mm)

G_e=Groundwater contribution from water table (mm)

W_b=Water stored in the soil at the beginning of each period (mm)

D=Deep percolation/drainage (mm)

LR=Leaching requirement (mm)

Again if the estimated LR is found be less than 10%, it is ignored from the equation.

As a rule, under drip irrigation conditions of high water tables are rare and as a result groundwater contribution to crop water requirements is normally ignored. Similarly deep percolation was assumed to be zero. If assuming that W_b, G_e and D are zero, then the equation becomes:

IR_n=ETc - P_e + LR (mm)

Again if the estimated LR is found be less than 10%, it is ignored from the equation.

Gross irrigation: Gross irrigation requirement is net irrigation requirement plus losses in water application and other losses [12]. This is expressed in terms of overall efficiencies when calculating gross irrigation requirements from net irrigation requirements:

$$IR_g = \frac{IR_n}{E} + LR$$

Where,

IR_g=Gross irrigation requirements (mm),

IR_n=Net irrigation requirements (mm),

E=Field efficiency of the system (drip system assumed to be 85% [10]

Daily irrigation, the amount of water was adjusted according to existing reference *ET* and *Kc*. The irrigation treatments were differentiated by their two meters arrangement for strip, irrigation events were controlled manually by using valve. The valve was put on and off after calculating net irrigation and adding losses (gross) depending on amount of water to be applied at desired level for each strip separately. Records of daily applied water were kept from the start of treatment application up to the final harvest date for each treatment. The records daily applied water was then summed up for each treatment.

Adjustments for Kc for development and late stage and for partial wetting: The values of Kc of tomato used (0.6, 1.15 and 0.80 respectively, in the initial, mid and late season stages) Allen et al. [9]. During the initial and mid-season stages Kc is constant and equal to the Kc value of the growth stage under consideration (*Anon.*); these growth stage represent 25 days for the initial, 34 days for the development, 20 days for mid and 41 days for the late growing stages totalizing 120 days as recommended by Allen et al. [9].

The daily Kc for developmental and late season stages was adjusted using the formula given by Allen et al. [9]. During the crop development and late season stages, Kc varied linearly between the Kc at the end of the previous stage (Kc prev) and the Kc at the beginning of the next stage (Kc next), which is Kc end in the case of the late season stage. The partial wetting for wetting patterns of the drip emitters was measured from sample drippers and adjusted to 0.3 ratios.

Data collection

All yield data such as marketable fruit yield, unmarketable fruit yield were measured at each harvesting and summed up at end of the experiment and the total fruit yield was obtained by adding all fruit yields.

Estimation and quantifying crop water use

Tomato yield response (*Ky*): Water productivity behaviour of 'Tomato variety *'Melkasholla'* and its yield response to water' (*Ky*) was estimated through the following relationship described by Doorebos et al. [13].

$$(1-\frac{Y_a}{Y_m}) = Ky(1-\frac{ET_a}{ET_m})$$

Where,

Y_m=Maximum yield (kg)

Y_a=Actual yield (kg)

ET_m=Maximum evapotranspiration (mm/period)

ET_a=Actual evapotranspiration (mm/period)

All data analyse and methods of testing were very similar to the one described in Chapter 5. Data from this experiment were subjected to analyse of variance as strip plot design using linear). Where ever the treatments were significant means were separated using the LSD test at *P*=0.05 probability significance level.

Validation of CropWat

With the help of the CropWat model, the yield reduction will be determined and compared with the actual measured yield reduction of field experimentation using drip experiment. The yield reductions will be expressed as percentage of the tomato yield obtained under full irrigation [12-14].

Results and Discussions

Fruit yields

Use of various irrigation depths brought a significant (P<0.01) effect on the marketable yield of tomato whereas application of various irrigation depths did not bring significant difference (P<0.05) on unmarketable fruit yield of tomato (Table 1). Use of various irrigation depths had a significant (P<0.05) on the total fruit yield of tomato.

The mean separation indicated that the highest fresh fruit yield was obtained from full irrigation and the lowest was obtained from 60% irrigation water with saving of 40% of irrigation water (Table 2). Thus, the total fresh fruit yield obtained from fully irrigated tomato plot exceeded the fresh fruit yield obtained from tomato plot irrigated with only 60% of full irrigation water by 62.8% [15-18]. The results showed that with decrease in the depth of irrigation, there was a decrease in total fruit yield in tomato due to reduced uptake of water (Table 2). The result of this study corroborate that of Muchovej et al. [19] who reported that high quality and yield of vegetable crops are directly associated with proper water management. Birhanu and Katema also found that the fresh fruit yields of *Melkasholla* variety was reduced under deficit irrigation level. Similar findings were reported by Kirnak et al. [8] where egg plants grown under high water stress had less fruit yield and quality than those in the control treatment. Consistent with the results of this study also found that water stress in

Sources of variations	df	Mean square value		
		Marketable fruit yield	Unmarketable fruit yield	Total fruit yield
Irrigation	2	55159.9**	861.09 NS	4397.91*
Error	4	917.8	339.72	315
Total	44			
CV		22.94	28	8.92
Note NS=Indicates non-significant at *P*<0.05; *significant at *P*<0.05 and **significant at *P*<0.01 probability levels, respectively				

Table 1: Mean square values of vegetative growth yield and yield components parameters of tomato as influenced by integrated nutrient managements and application of various moisture regimes.

Irrigation regimes	Marketable fruit	Unmarketable yield	Total fruit yield
	(t ha^{-1})	(t ha^{-1})	(t ha^{-1})
IR I (100% ETc) (Full irrigation)	63.63 A	18.267	81.902 A
IR II (80% ETc)	33.83 B	22.413	56.250 B
IR III (60 % ETc)	27.82 B	23.062	50.868 C
Mean	41.765	20.813	62.916
LSD (0.05)	9.712	NS	5.689
*=Average of three replications. Means within each column with different letters are significantly different at LSD at P=0.05 level of probability			

Table 2: Mean values of various irrigation regimes on fruit yield of tomato grown under drip irrigated condition.

the container grown eggplants produced a very significant reduction in both dry biomass, they found that eggplant fruit yield was reduced by up to 68% in the water stressed plants compared with unstressed plants. Studento et al. [7] also reported that restricted water supply for tomato can suppress new leaf development, resulting in a shortened yield formation period. Similar findings were reported by that water stress significantly reduced final yield of field-grown sweet pepper. Similar findings were obtained where increasing irrigation increased total tomato fruit yield.

Irrigation positively influenced tomato productivity; the result was attributed to the increase in the number of berries per plant and the fruit average weight as irrigation increased. The authors concluded that the total yield and marketable tomato yields were decreased significantly as the deficit level was increased. The reduction in total yield of tomato with an increased amount of water stress level of this test was consistent with previous work conducted on tomato and other crops such as cotton as reported [20].

Irrigation positively influenced tomato productivity; the result was attributed to the increase in the number of berries per plant and the fruit average weight as irrigation increased. The authors concluded that the total yield and marketable tomato yields were decreased significantly as the deficit level was increased. The reduction in total yield of tomato with an increased amount of water stress level of this test was consistent with previous work conducted on tomato and other crops such as cotton as reported [21].

Water production function of tomato under various irrigation scenarios

The relationship between yield and irrigation water applied was sketched in Figure 1. Based on the relationship tested, about 92% of the variation in fresh fruit yield was brought about by irrigation regime treatments (Figure 1). Thus, as irrigation depth increased, total fruit yield increased linearly.

The relationship between yield and irrigation water supplied could be expressed by a linear relationship very well as: *Fresh tomato fruit yield =28.95x -2811, with* R^2*=0.918*; with a slope of about 28.9:1 in terms of reduced applied water: gross kg yield reduction. Bazza conducted an experiment for sugar beet concluded that more than 90% of the yield variation was coming from the variability in depth of irrigation applications.

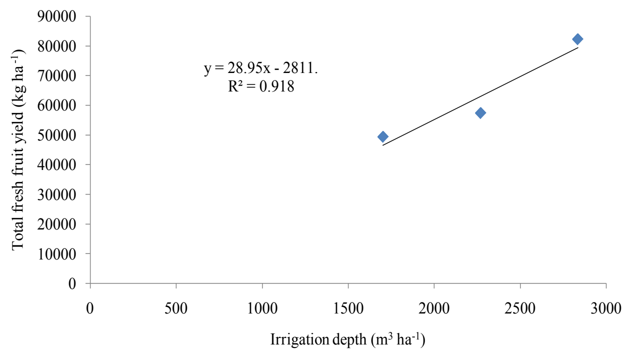

Figure 1: Yield-water relationship (water production function) of drip irrigated tomato *Melkasholla* variety grown under dry and hot season at Melkassa.

Estimation of yield response (Ky)

Relationship between relative yield decrease (1-Ya/Ym) and relative evapotranspiration (1-ETa/ETm) of tomato at Melkassa, yield response to water' (*Ky*) was determined through the functional relationship described by Doorebos et al. [14]. Thus the yield response (*ky*) of tomato *Melkaskola* variety at Melkassa was calculated and estimated to be 0.9998 a little bit lower than given by Allen et al. [9] which was 1.05 value (Figure 2).

Although tomato is relatively moderately sensitive crop, and the *Ky* is estimated to be 1.05 Allen et al. [9] many authors such as Getta, Giardini and Giovanardi found variable value of *Ky*. The relationship between relative yield decrease (1-Ya/Ym) and relative evapotranspiration (1-ETa/ETm) of tomato at Melkassa was determined through the functional relationship. Thus the yield response (*ky*) of tomato *Melkaskola* variety throughout the crop cycle at Melkassa was calculated and estimated to be 0.999 indicating the yield reduction in tomato is directly proportional to reduced water use Studento et al. [7] and it is a little bit lower than given by Allen et al. [9] which was 1.05 value (Figure 2).

In this figure, *Ky*=1 is shown as a reference line, and *Ky*=1.05 is also shown as a reference line.

Validation of CropWat for tomato

Different levels of irrigation water were applied to tomato crop

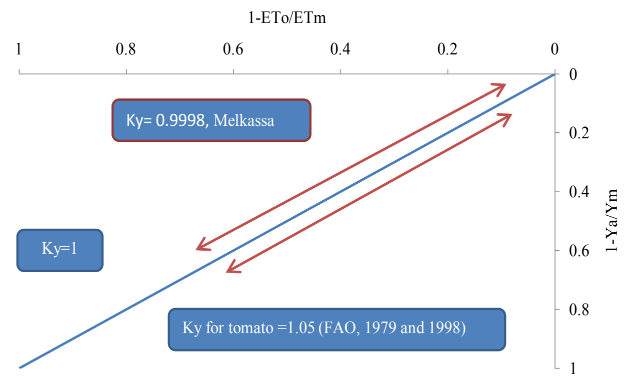

Figure 2: Predicted values and regression line of the functional relationship between relative yield reductions (1-Ya/Ym) and relative evaporation deficits (1-ETa/ETm) of tomato *Melkasholla* variety.

Irrigation treatment	Measured		CropWat
	Yield (kg ha^{-1})	Yield reduction (%)	Yield reduction (%)
Full ETo	82140	0	0
80% ETo	57300	30.24	19
60% ETo	49300	39.98	34.1

Table 3: Comparisons between yield reductions simulated by CropWat and measured for drip irrigated tomato experiment at Melkassa.

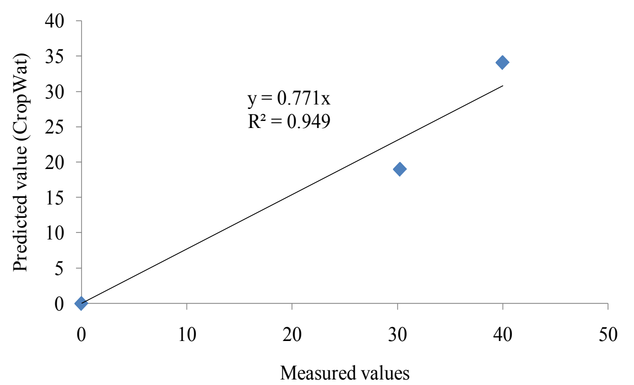

Figure 3: Comparisons of predicted and measured tomato yield reduction under different irrigation regimes at Melkassa.

during the field experiment, inducing water stress throughout the growing season. With the help of the CropWat model the yield reduction was determined and compared with the actual yield reduction of field experimentation [22,23]. Table 3 presents comparison of measured yield reduction with the yield reductions simulated by the CropWat model. The yield reductions were expressed as percentage of the tomato yield obtained under full irrigation.

The CropWat simulation model was combined with 35-year local historical weather data and used as a research tool.

The observed and simulated values for yield are plotted in Figure 3. The model efficiency was calculated and estimated through comparing predicted values to the one-to-one line rather than the best regression line through the origin points. Accordingly, the model efficiency was found to be 94%. This model efficiency was similar to the correlation (r^2) and the r^2 was found to be 95.1% (Figure 3). The measured and simulated tomato total fruit yield showed a good correlation. Furthermore, the simulated results reflected that the impact of stress in the whole tomato growth cycles was high on fresh fruit yield reduction. The model was confirmed to be a useful decision support system to help farmers to verify the optimal crop management strategy from several points of views.

Summary and Conclusions

An irrigation experiment with drip method was conducted to evaluate and determine the optimal irrigation levels for maximum tomato production, to assess the effect of limited water supply on field grown tomato yield and to estimate 'yield response of tomato to soil water (Ky)' and to validate CropWat irrigation model using the data for tomato cultivation during hot-dry season conditions around Melkassa. Three levels of irrigation regimes with three replications. Among irrigation levels tested, highest yield of 82.14 t ha^{-1}, was recorded from full irrigation treatment (100% ETc) followed by 57.30 t ha^{-1} from 80% ETc irrigation levels and lowest yield 50.86 t ha^{-1} from 60% ETc irrigation depth. This indicated that tomato crop should be irrigated at full water requirement to get maximum fruit yield. The relationship between relative yield decrease (1-Ya/Ym) and relative evapotranspiration (1-ETa/ETm) of tomato at Melkassa was determined through the functional relationship and the yield response (*ky*) of tomato *Melkaskola* variety throughout the crop cycle was calculated and estimated to be 0.999 indicating the yield reduction in tomato is directly proportional to reduced water use. This figure is a little bit lower than given by Allen et al. [9] which were 1.05 value. With the help of the CropWat model, the yield reduction simulated by the CropWat was compared with the actual yield reduction of field experimentation. The model efficiency was calculated and estimated through comparing predicted values to the one-to-one line rather than the best regression line through the origin points. Accordingly, the model efficiency was found to be 94%. This model efficiency was similar to the correlation (r^2) and the r^2 was found to be 95.1%. The measured and simulated tomato total fruit yield showed a good correlation. Furthermore, the simulated results reflected that the impact of stress in the whole tomato growth cycles was high on fresh fruit yield reduction. The model was confirmed to be a useful decision support system to help farmers to verify the optimal crop management strategy from several points of views. This further confirm that for rainfed tomato, supplementary irrigation should be switched on during dry spells, and full irrigation should be started on immediately after the rain fall cessation; otherwise much yield loss would occur. This experiment was conducted under drip irrigation conditions whereas all household growers in the study area practice furrow irrigation, thus appropriate irrigation method and irrigation depth estimation should be envisaged in the future for household irrigation water users that maximise yield, improve crop water use.

References

1. Etissa E, Dechassa N, Alamirew T, Alemayehu Y, Dessalegne L (2014) Response of Fruit Quality of Tomato Grown under Varying Inorganic N and P Fertilizer Rates under Furrow Irrigated and Rainfed Production Conditions in the Central Rift Valley of Ethiopia. International Journal of Development and Sustainability 3: 371-387.
2. Etissa E, Dechassa N, Alamirew T, Alemayehu Y, Dessalegne L (2014a) Irrigation Water Management Practices in Small Scale Household Vegetable Crops Production System: The Case of the Central Rift Valley of Ethiopia. Science, Technology and Arts Research Journal 3: 74-83.
3. Sijali IV (2001) Drip Irrigation: Options for Smallholder Farmers in Eastern and Southern Africa. RELMA Technical Hand Book Series 24. Kenya.
4. Hochmuth G, Hanlon EA (2010) Commercial Vegetable Fertilization Principles. The Institute of Food and Agricultural Sciences (IFAS).

5. Cowater International Inc REST (2003) Studies on Water Harvesting Technologies and their Applications in the Region of Tigray. USA.
6. Etissa E, Dechassa N, Alamirew T, Alemayehu Y, Dessalegne L (2014b) Growth and Physiological Response of Tomato to Various Irrigation Regimes and Integrated Nutrient Management Practices. African Journal of Agricultural Research 9: 1484-1489.
7. Studento P, Hsiao TC, Fereres E, Raes D (2012) Crop Yield Response to Water. FAO. Irrigation and Drainage Paper 66. Italy.
8. Kirnak H, Cengiz K, Ismail T, David H (2001) The Influence of Water Deficit on Vegetative Growth, Physiology, Fruit Yield and Quality in Eggplants. Bulg J Plant Physiol 27: 34-46.
9. Allen RG, Pereira LS, Raes D, Smith M (1998) Crop Evapotranspiration (Guidelines for Computing Crop Water Requirements). Irrigation and Drainage Paper No 56. Italy.
10. Muchovej RM, Hanlon EA, McAvoy E, Ozores-Hampton M, Roka FM, et al. (2008) Management of Soil and Water for Vegetable Production in Southwest Florida. Institute of Food and Agricultural Sciences.
11. Doorenbos J, Kassam AH (1979) Yield Response to Water. Irrigation and Drainage Paper 33. Food and Agricultural Organization. Italy.
12. Doorenbos J, Pruitt WO (1977) Guidelines for Predicting Crop Water Requirements. FAO. Irrigation and Drainage Paper 24. Italy.
13. FAO (2009a) ETo Calculator Version 3.1: Land and Water Division. Italy.
14. FAO (2009b) CROPWAT Version 8.0.
15. Hazelton P, Murphy B (2007) Interpreting Soil Test Results. CSIRO Publishing. Australia.
16. Hegde DM, Srinivas K (1989) Studies on Irrigation and Nitrogen Requirement of Tomato. Indian Journal of Agronomy 34: 157-162.
17. Micheal AM (2008) Irrigation Theory and Practice (2nd edn.). Vikas Publishing. India.
18. Fekadu M (2006) Evaluating Small-scale Drip Irrigation System: An Option for Water Harvesting-based Smallholder Farmers' Vegetable Production in Amhara Region. pp: 158.
19. Raes D, Willems P, Gbaguidi F (2006) RAINBOW - A Software Package to Compute Frequency Analyze and Perform Testing of Homogeneity on Hydrometeorological Data Sets. IRRISOFT Software Descriptions and Reviews.
20. Scholberg J, Brian L, McNeal, Jones JW, Boote KJ, et al. (2000) Field-Grown Tomato: Growth and Canopy Characteristics of Field-Grown Tomato. Agron J 92: 152-159.
21. Singh GB, Yadav DV (1992) Integrated Plant Nutrition System in Sugarcane. Fertilizer News 37: 15-22.
22. Spiers JM, Braswell JH (1994) Response of 'Sterling' Muscadine Grape to Calcium, Magnesium, and Nitrogen Fertilization. J Plant Nutr 17: 1739-1750.
23. Bikila T (2007) The Income Contribution of Ziway Lake to Smallholder Farmers and Fishing Households and its Implications for the Sustainability of the Water and Fish Resources. pp: 166.

Citation: Etissa E, Dechassa N, Alemayehu Y (2016) Estimation of Yield Response (Ky) and Validation of CropWat for Tomato under Different Irrigation Regimes . Irrigat Drainage Sys Eng 5: 167. doi:10.4172/2168-9768.1000167