Determination of Irrigation Regime for Hot Pepper in Dry-Land Areas of Wag-Himra, North Eastern Amhara.

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Abstract

A field experiment was conducted in 2014 and 2015 in Ziqualla and Abergelle woreda. This field experiment was therefore conducted to determine net irrigation requirements and irrigation schedules of hot pepper using CROPWAT computer model and to validate using field trial. A split plot design with the main plot of water depth and subplot of irrigation frequency has been used. Three levels of water amount with (I_1), (I_2), and (I_3) CROPWAT generated depth and three levels of irrigation frequency at (5), (7) and (9) days were used as a treatment. Additionally, one treatment farmer practice of irrigation depth and interval has been used as a control. The experimental result showed that irrigation application of I_1 CROPWAT generated depth at 5 days irrigation interval obtained a relatively higher and statistically significant marketable yield, water productivity on both Ziqualla and Abergelle. , Congruently, in terms of economic profitability, it was found that irrigation application I_1 CROPWAT generated depth at 5 days irrigation interval had 7.7 ton/ha and 6 ton/ha economical yield advantageous as compared to the irrigation application of I_2 CROPWAT generated depth with 7 days irrigation interval on Ziqualla and Abergelle. Considering the above results, irrigation application of I_1 CROPWAT generated depth at 5 days interval was found economically feasible and recommended to improve crop and water productivity of the irrigation schemes by saving a significant amount of water for irrigating additional lands for hot pepper crop production both in Ziqualla and Abergelle small-scale irrigation schemes.

Keywords: Hot pepper, Irrigation regime, Marketable yield, Wag-himra, Water productivity,

Introduction

Hot pepper *(Capsicum annum L.)* is an important commercial crop, cultivated for vegetable, spice, and value-added processed products (Nalla *et al.*, 2017). It originated from the American with their cultivars are now grown around the world because they are widely used as food and medicine (Mazourek *et al.*, 2009). Peppers are one of the most susceptible horticultural crops to drought stress due to its broad range of transpiring leaf surface, high stomatal conductance(Alvino *et al.*, 1994) and shallow root system (Kulkarni and Phalke, 2009, Liu *et al.*, 2012). Pepper production accounts for 34% of the total spice production in the three regions of Ethiopia namely Amhara, Oromia and Southern Nations Nationalities and Peoples Regional States (Roukens *et al.*, 2005). FAO, (2009) report indicated that the estimated production of peppers in Ethiopia was 220,791ton from 97,712 ha in green form and 118,514 ton of dry pepper from an area of 300,000 ha.

Increase in population has led to an upsurge in the demand of food (pepper) and fiber which has also resulted in the adoption of irrigation to sustain plant growth(Delfine *et al.*, 2001). As population rises and development calls for the distributions of ground and surface water for domestic, agriculture and industrial sectors augmented; as a result, the pressure on water resources strengthens. The increasing stress on freshwater resources transported about by an ever-rising demand for water is of thoughtful concern (FAO, 2008).

Notwithstanding the increase in water use by subdivisions other than agriculture, irrigation carries on to be the main water user on a worldwide. Irrigated agriculture consumes more than 70% of the water demanding from the rivers of the world and for the developing world; the proportion can reach 80% (FAO, 2002). The condition is no more different in Ethiopia. It has been obviously and noisily stated that if Ethiopia is to feed its ever-increasing population, lessen the risk of disasters caused by drought, and increase population density in the dry and thinly populated areas, incessant and extensive effort need to be made towards developing irrigated agriculture and intensifying agricultural production. Irrigation will, therefore, play a progressively important role now and in the upcoming both to increase the yield from already refined land and to permit the cultivation of what is today called marginal or unusable land due to moisture deficiency.

Water availability is the most limiting factor for crop production in the dry-land areas of Ziqualla and Abergelle. Moreover, lack of crop water requirement studies for major crops had been a challenge for appropriate utilization of scarce water resource in irrigated agriculture and it leads to low water use efficiency through improper irrigation scheduling.

Determination of water requirement of the crop, appropriate irrigation scheduling can be designed, which can lead to improvements in the yield, income, and water saving(Bossie *et al.*, 2009). To ensure the highest crop production with the least water use, it is important to know the water requirement of the crops(Tyagi *et al.*, 2000). This improves the efficient and economic use of irrigation water. However, effective irrigation water management 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 to the plot of land will cause to extra pumping costs, wasted water due to evaporation and runoff, and increased risk for leaching valuable agrichemicals below the rooting zone.

Proper timing of irrigation water applications is therefore an important decision tool for a farm manager to meet the water needs of the crop, to prevent yield loss due to water stress, and for maximizing the irrigation water use efficiency which resulted in beneficial use and conservation of the scarce water resources, and minimize the leaching potential of nitrates (Valipour, 2015). Ziqualla and Abergelle woreda, small-scale irrigation scheme is typically applied on a monotonous basis without scheduling and inadequate management of irrigation water has been an important limiting factor to pepper production. Growers generally lack knowledge on features of soil-water-plant relationship and they apply water to the crop irrespective of the plant needs. They seem to relate irrigation occurrence to days after planting with fixed intervals and water amounts rather than to crop stage progress. The knowledge of proper irrigation scheduling, when to irrigate and how much water to apply, is essential to optimize crop production per unit water and for sustaining irrigated agriculture on permanent footing(Kirda, 2002). Therefore, this study was conducted with the objective of determining the net irrigation requirements and irrigation schedules of hot pepper using CROPWAT computer model and to validate using a field trial.

Material and methods

A field experiment was conducted during 2014 and 2015 in Ziqualla and Abergelle district, Wag Himra Administrative Zone of Amhara Region (Figure 1). The study sites are located at 1414332N and 475070E at Ziqualla; 1425280N and 495749E at Abergelle. The altitude of the study areas are 1465m and 1260m Ziqualla and Abergelle m.a.s.l respectively. The soil samples from the study area were collected and analyzed, characterized the soil at Sekota dry land agricultural research center (SDARC)and Mekelle university soil laboratory. The sites are characterized by clay texture soils. The soil particle size distribution of clay, silt, and sand is 41.29%, 29.92%, 28.79% at Ziqualla and 41.3%, 26.7%, 32% at Abergelle, respectively (SDARC Soil Laboratory). The soil moisture content field capacity and permanent wilting point of the sites are 32.92% and 19.03% for Ziqualla and 32.51% and 16.28% for Abergelle (Mekelle University soil Laboratory).

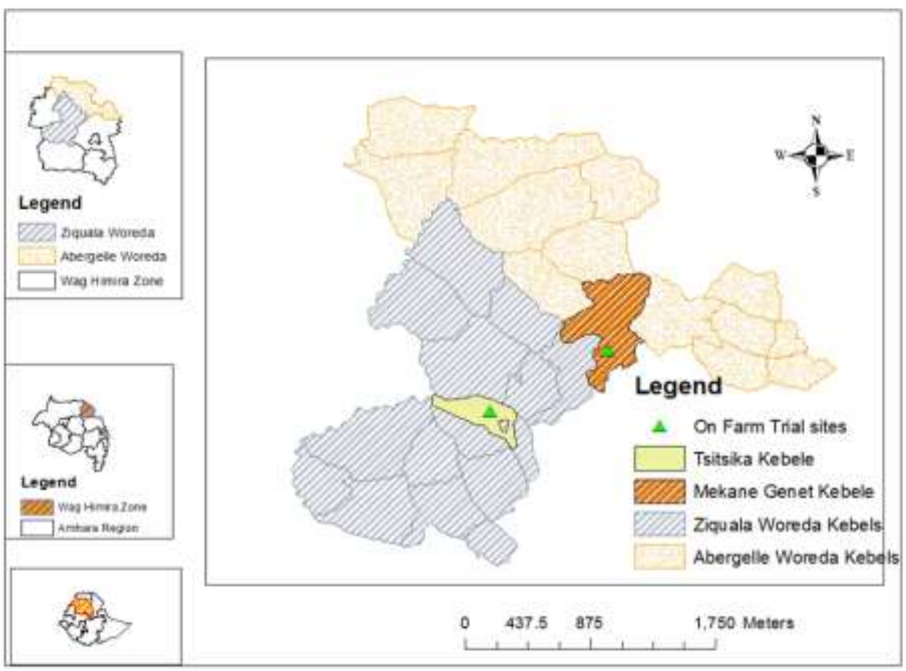

Figure1. Location map of study areas

Experimental setup

The experimental design was split plot with replicated three times. The experimental plot of 2.8m by 3m was used to test irrigation regimes. Hot pepper (Marko fana) was selected as the test crop. The selected marko fana has a production cycle of 125 days including transplanting up to second harvesting with the initial crop growth stage of about 20 days, crop development stage of 35 days, mid-season stage of 50 days and late season stage of 20 days, which was derived from CROPWAT software. Plant spacing was set at 70cm and 30cm between rows and plants, respectively. Blanket recommended fertilizer rate of Dia Ammonium Phosphate (DAP) 100kg/ha at transplanting and urea fertilizer of 100kg/ha at half transplanting and half 45 days was applied in both experimental sites. Both diseases and weed infestations were regularly monitored, and proper management action has been undertaken timely. Cutworms were observed during the early seedling establishments on the actual field, whereas Fusarium wilt was a problem at a vegetative and plant development stages. Karate and Mancozeb (3kg/ha) were used to control the disease infestation which was practiced according to the label in the bag.

CROPWAT optimum depth and interval was considered as a benchmark to set ten irrigation regime treatments including farmers practice. A split-plot design with three replications was used at which water depth assigned as main plot and interval as subplot treatments. The depth of irrigation was fixed at (I3), (I2), and (I1) of optimum CROPWAT generated depth and irrigation interval of (5), (7), and (9) days. The hand held watering cane was used to measure the amount of water entering in to each furrow with the experimental plot(Yihun, 2015).

Table 16. CROPWAT fixed application depth and optimal time of application on amount of applied water (mm) treatments in the experimental area.

Treatments	Amount of applied water(mm)	
	Ziqualla	Abergelle
125% (I3)CROPWAT fixed depth (and optimal time of application at 5-day interval	455.3	445.7

Determination of Crop Water Requirement using CROPWAT

The amount of water needed (CWR) to compensate the amount of water lost through evapotranspiration (ETc), requires reference evapotranspiration (ETo) and hot pepper crop coefficient (Kc) given by (Allen *et al.,* 1998) as 0.5 for the initial stage, $0.5<Kc<1.15$ for the crop development stage, 1.15 for the mid-season stage and 0.6 for the late season stage. Calculation of crop water requirement (ETc) using CROPWAT software over the growing season was from ETo and crop coefficient (Kc).

$ETc=ETo*Kc$--Equation (1)

Where, ETc = actual evapotranspiration (mm/day), Kc = crop coefficient, and ETo = reference crop evapotranspiration (mm/day). The net irrigation requirement was calculated using the CROPWAT software based on (Allen *et al.,* 1998) as follows:

$IRn=ETc-Pe$---Equation (2)

Where, IRn =Net irrigation requirement (mm), ETc in mm and Pe = effective rainfall (mm) which is part of the rainfall that enters into the soil and makes available for crop production. The effective rainfall (pe) was estimated using the method given by (Allen *et al.*, 1998) as.

$Pe = 0.6 * P - 10/3$ for P month $<= 70$ mm or--Equation (3)

$Pe = 0.8 * P - 24/3$ for P month > 70 mm---Equation (4)

Where, Pe (mm) = effective rainfall and P (mm) = total rain fall.

Composite soil samples were collected from field plots and the soil textural analysis was done by hydrometer and soil textural class was determined from soil textural triangle. Field capacity, permanent wilting point, and moisture at saturation were determined using Pressure plate apparatus from laboratory analysis of soil samples. Total Available Moisture (TAM) in the soil for the crop during the growing season was calculated as field capacity minus wilting point times the rooting depth of the crop.

Readily Available Moisture (RAM) was calculated as TAM*P, Where P is the depletion fraction as defined by the crop coefficient (Kc) files. Water productivity, also known as water use efficiency, was determined as the ratio of crop yield per unit area, in terms of grain, to crop evapotranspiration (mm), and was expressed as kg of grain or biomass per m^3 of consumed water.

$$\text{water productivity}\left(\frac{\text{kg}}{\text{m3}}\right) = \frac{\text{Total yield of green pepper}}{\text{water delivered up to harvesting}}$$

Data analysis

All the agronomic data like plant height, pod length, pod diameter, canopy diamter, yield and water productivity were recorded and being subjected to analysis. Analysis of variance and correlation was performed using SAS Statistical Software Version 9.1. Effects were considered significant in all statistical calculations if the P-values were ≤ 0.05. Means were separated using Fisher's Least Significant Difference (LSD) test.

Results and Discussion

The result revealed that I1 and I2 CROPWAT generated depth using 5 and 7days irrigation interval improved marketable yield, total yield and water productivity of hot pepper production respectivly. But farmers' irrigation scheduling and depth application practices provided low yield gain because of more apply water and some of gap irrigation intervals cause water logging, plants are not freely aired. In general, I1 CROPWAT generated depth at 5 days irrigation interval provided a better yield and yield related components (Table 2). The result in agreement with the finding of (Yang *et al.*, 2017) who stated that water deficit from reducing irrigation amounts to 1/3 to 2/3 of full irrigation during the development and mid season stages did not affect pepper yield; compared with full irrigation, the water deficit even increased fruit yields. These results occurred mainly because the water content under deficit irrigation in the study by (Yang *et al.*, 2017) still reached higher than 70% of FC, which is sufficient for pepper growth (Liu *et al.*, 2012). At the same time, full irrigation with a water content of 100% of FC in their study is very high and can reduce pepper yields (Liu *et al.*, 2012). This study could be used for irrigating an additional land of 0.28 ha. The finding was in line with (Serna and Zegbe, 2012) who described in the hot pepper study, a water deficit of 15–45% application can conserve 8–30% of irrigation water, compared with full irrigation. Moreover, those study I1 CROPWAT generated depth application at 5 days irrigation interval as compared to farmer's practice, irrigation scheduling and application depth saved 5028m^3/ha amount of irrigation water (Table 1). This amount of irrigation water could be used to irrigate an additional irrigation land of 2.2ha with a yield benefit of 25.2ton/ha of hot pepper crop production.

Table 17. Interaction effects of depth and frequency on marketable yield, total yield, and water productivity on Ziqualla.

	Total yield(ton/ha)				Marketable yield(ton/ha)				Water productivity(kg/m^3)			
	Depth				Depth				Depth			
Frequency	I1	I2	I3	Fd	I1	I2	I3	Fd	I1	I2	I3	Fd
5 days	11.5	9.3	9.2		11.2	9.0	8.9		5.06	3.85	2.63	
7 days	9.1	11.6	9.1		8.8	11.3	8.8		2.86	4.55	2.87	
9 days	3.1	3.1	3.4		2.8	2.7	3.1		1.82	1.56	1.33	
Ff				5.7				5.4				1.64
LSD	0.9				1.0				0.57			
Cv (%)	10.09				10.13				15.21			

Where, I1=75% crop water requirement, I2=100% crop water requirement, I3=125% crop water requirement, Fd=farmer practice irrigation depth, Ff=farmer practice irrigation interval.

There were non-interaction effects in both depth and frequency on pod length, pod diameter, number of pod per plant, plant height, canopy diameter and the unmarketable yield on Ziqualla experimental site. The optimum application of I1, I2, CROPWAT generated depth had better pod length, pod diameter and a number of pod per plant compared with irrigation application of farmers' practice. Considering the interval of the irrigation application, statistically, there was non-significance difference in terms of pod length, pod diameter, number of pod per plant, canopy diameter and unmarketable yield for 5 and 7 days interval.

For instance, the farmer's irrigation practices contributed to the lowest pod length of 6.42 cm whereas irrigation application with 5, 7, days irrigation interval had 9.4, 8.96 cm, respectively. This result was in line with (Delelegn, 2011) who informed that hot pepper which obtained a better pod diameter and pod length using Mareko Fana at Jimma areas. The result of I1 CROPWAT generated depth and irrigation application of 5 days irrigation interval offered the highest value for the yield and yield related parameters of Ziqualla experimental site (Table 3). The result indicated that the variability of the amount of water application and irrigation interval has a significant effect on yield and yield correlated component for hot pepper.

Table 3. Effects of depth and frequency on pod length, pod diameter, No pod per plant, plant height, canopy diameter and unmarketable yield at Ziqua1la experimental site.

Treatment	Pod length (cm)	Pod diameter (cm)	No of pod per plant	Plant height (cm)	Canopy diameter (cm)	Unmarketable yield (ton/ha)
Depth						
I1	9.06a	1.47a	18.78a	71.33a	39.34a	0.24a
I2	8.80a	1.45a	20.15a	70.62a	38.97a	0.27a
I3	8.92a	1.41a	19.65a	69.07a	38.01ab	0.26a
Fp	6.42b	1.18b	13.96b	64.30a	34.56b	0.27a
LSD	1.97	0.19	3.15	9.95	3.67	0.09
Cv (%)	17.09	10.57	12.47	10.71	7.18	27.14
Frequency						
5 days	9.40a	1.51a	23.85a	76.32a	42.28a	0.25a
7 days	8.96a	1.45a	22.36a	71.82ab	42.44a	0.24a
9 days	8.42a	1.37ab	12.37b	62.90b	31.60b	0.27a
Fp	6.42b	1.18b	13.96b	64.30b	34.56b	0.29a
LSD	1.97	0.19	3.15	9.95	3.67	0.09
Cv (%)	17.09	10.57	12.47	10.71	7.18	27.14

Correlation analysis between yield parameters was tested using t-test as shown in table 4. The result revealed that a highly correlation coefficient ($r \geq 0.9$) of marketable yield with a number of pod per plant, total yield, and water productivity. Similarly, water productivity had also a highly significant correlation (r≥0.8) with the number of pod per plant. However, unmarketable yield was negatively correlated with other parameters at $p<0.05$ probability (Table 4).

Table 18. Correlation coefficient of the different parameter (number of pod per plant, marketable yield, unmarketable yield, total yield, and water productivity) from the study data.

Parameters	Number of pod per plant	Marketable yield	Unmarketable yield	Total yield	Water productivity
Number of pod per plant	1				
Marketable yield	0.93***	1			
Unmarketable yield	-0.11ns	-0.15 ns	1		
Total yield	0.93***	0.99***	-0.12ns	1	
Water productivity	0.84**	0.90***	-0.13ns	0.90***	1

**** Very highly significant, ** Very significant, * significant, ns none significant*

There was an interaction effect both in depth and irrigation frequency on a number of pod per plant, marketable yield, total yield, and water productivity in Abergelle sites(Table 5). The effect indicated that irrigation application of I1 and I2 CROPWAT generated depth with 5 and 7 days irrigation intervals were recorded the highest pods per plant, marketable yield, total yield, and water productivity respectively. These results provided statistically significant pods per plant, marketable yield, total yield, water productivity compared with other treatments. They had a yield enhancement of 3.1ton/ha and 2.8 ton/ha in that order related to the farmer's irrigation application practices. In relationships of water productivity, irrigation application of CROPWAT generated depth I1 and I2 with 5 days irrigation interval, about 662m3/ha amount of irrigation water was saved which would like to irrigate an additional lands of 0.29 ha that produce 2.6 ton/ha. The yield variance between the two application depth was 3.7 ton/ha of hot pepper crop yield advantages by using I1 CROPWAT generated depth. In the same way, as compared to farmer irrigation practices, 5675m3/ha amount of irrigation water, which could confine to irrigate another land of 2.4ha that produces 22.1ton/ha yield gain of hot pepper production in Abergelle areas. (Zegbe-Dominguez et al., 2003, Kang et al., 2001) reported that for optimum irrigation scheduling, sound knowledge of the soil-water status, crop water requirements, crop stress status, potential yield reduction if the crops remain in stressed condition is required to maximize yield and optimizes water productivity.

Table 19. The interaction effects of depth and frequency on No of pod per plant, total yield, marketable yield and water productivity in Abergelle experimental site.

	No of pod per plant				Total yield (ton/ha)				Marketable yield(ton/ha)				Water productivity(kg/m^3)			
	Depth				Depth				Depth				Depth			
Frequency	I1	I2	I3	Fd	I1	I2	I3	Fd	I1	I2	I3	Fd	I1	I2	I3	Fd
5 days	19.6	17.6	17.3		9.2	8.0	7.6		8.8	7.8	7.2		4.10	3.14	2.00	
7 days	13.9	20.0	18.7		7.8	8.9	7.9		7.5	8.6	7.5		2.92	4.09	2.73	
9 days	10.4	12.9	14.4		3.0	2.8	3.0		2.6	2.5	2.7		1.91	1.29	1.19	
Ff				13.0				6.0				5.7				0.88
LSD	2.30				0.7				0.7				0.35			
Cv (%)	10.96				8.35				8.89				10.97			

Where, I1=75% crop water requirement, I2=100% crop water requirement, I3=125% crop water requirement, Fd=farmer practice irrigation depth, Ff=farmer practice irrigation interval.

Not at all interaction effects in both depth and frequency on pod length, pod diameter, plant height, canopy diameter and unmarketable yield of a hot pepper crops trendy instance of Abergelle. Since, irrigation interval point of view, the table exhibited that there were the non-significance difference between irrigation application of 5 and 7 days in terms of pod length, pod diameter, plant height, and canopy diameter.

Table 20. Effects of depth and frequency on pod length, pod diameter, plant height, canopy diameter and the unmarketable yield on Abergelle.

Treatment	Pod length (cm)	Pod diameter (cm)	Plant height (cm)	Canopy diameter (cm)	Unmarketable yield (ton/ha)
Depth					
I1	8.41a	0.80ab	69.90a	39.48a	0.31ab
I2	8.21a	0.85a	69.02a	37.91ab	0.25b
I3	8.24a	0.86a	68.95a	38.05ab	0.34a
Fd	7.41a	0.65b	68.00a	32.26b	0.33ab
LSD (0.05)	1.67	0.15	9.66	6.90	0.08
Cv (%)	15.28	13.94	10.49	13.68	19.72
Frequency					
5 days	9.46a	0.93a	72.22a	41.82a	0.35a
7 days	8.83ab	0.90a	70.87a	41.65a	0.27b
9 days	6.58c	0.67b	64.77a	31.97b	0.28ab
Ff	7.41bc	0.65b	68.00a	32.26b	0.33ab
LSD (0.05)	1.67	0.15	9.66	6.90	0.08
Cv (%)	15.28	13.94	10.49	13.68	19.72

The correlation coefficient analysis such as indicated that marketable yield was significantly correlated ($r \geq 0.9$) with total yield, and also water productivity was significantly correlated through marketable yield and total yield ($r \geq 0.8$), but negatively correlated with unmarketable yield (Table 7). The t-test analysis for correlation coefficient with 95% confidence interval showed that there was a significant difference in all the parameters except unmarketable yield.

Table 21. Correlation coefficient of different parameters (number of pod per plant, marketable yield, unmarketable yield, total yield, and water productivity) from the study data.

Parameters	Number of pod per plant	Marketable yield	Unmarketable yield	Total yield	Water productivity
Number of pod per plant	1				
Marketable yield	0.78*	1			
Unmarketable yield	0.04ns	0.09 ns	1		
Total yield	0.78*	0.99***	0.12 ns	1	
Water productivity	0.73*	0.81**	-0.08ns	0.80 **	1

(*** Very highly significant, ** Very significant, * significant, ns none significant*

Conclusion and recommendation

The results of the experiment was conducted at Ziqualla, Tsitsika small-scale irrigation scheme, and Abergelle, Bahir small-scale irrigation scheme. Application of irrigation depth at specific irrigation interval has shown a significant effect on yield and water productivity when compared with farmers' irrigating practices. Irrigation application of I1 and I2 CROPWAT generated depth at 5 and 7 days irrigation interval provided a relatively significant and higher value in terms of yield and yield related parameters including marketable yield and water productivity both on Ziqualla and Abergelle. Comparing with farmers' practice, I1 CROPWAT generated depth at 5 days irrigation intervals saved irrigation water that would irrigate an additional land of about 2.2ha on Ziqualla and 2.4ha on Abergelle. Hence, research intervention was very important for improving crop production by saving a significant amount of water for irrigating the additional land in the study areas.

However, considering the economic advantage of water productivity between I1 CROPWAT generated depth at 5 days irrigation interval and I1 CROPWAT generated depth at 7 days irrigation interval, I1 depth at 5 days interval had a relatively higher yield advantage of 7.8 ton/ha and 6.1ton/ha on Ziqualla and Abergelle, respectively. Considering this, the irrigation application of I1 CROPWAT generated depth at 5 days irrigation interval was found economically feasible. Accordingly, it is recommended to be used by the farmers and other water users in Ziqualla and Abergelle woreda and other similar agro-ecological zones. Furthermore, further research on fertilizer rate for hot pepper under irrigation is suggested.

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