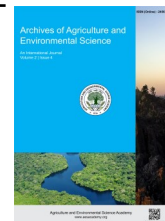This content is available online at AESA

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ORIGINAL RESEARCH ARTICLE

CrossMark

Determination of irrigation regime for hot pepper (*Capsicum annum* L.) in dry-land areas of Wag- Himra, North Eastern Amhara, Ethiopia

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ABSTRACT

A field experiment to evaluate CROPWAT model estimations was conducted during the year 2014 and 2015 on Ziqualla and Abergelle. This field experiment was therefore conducted to determine net irrigation requirements and irrigation schedules of hot pepper (*Capsicum annum* L.) 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 (I1), (I2), and (I3) CROPWAT generated depth and three levels of irrigation frequency at (5), (7) and (9) days interval were used as a treatment. Additionally, one treatment farmer practice irrigation depth and interval has been used as a control. The experimental result showed that irrigation application of I1 CROPWAT generated depth at 5 days irrigation interval obtained a relatively higher and statistically significant marketable yield, water productivity on both Ziqualla and Abergelle. In terms of economic profitability, it was found that irrigation application I1 CROPWAT generated depth at 5 days irrigation interval had 7.7ton/ha and 6ton/ha economically yield advantageous associated that I2 CROPWAT generated depth with 7 days irrigation interval on Ziqualla and Abergelle, congruently. Considering the above results, irrigation application of I1 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 (*C. annum*) crop production both Ziqualla and Abergelle small-scale irrigation schemes.

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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 produc-

tion in the three regions of Ethiopia namely Amhara, Oromia and Southern Nations Nationalities and Peoples Regional States (Roukens *et al.*, 2005). FAO, (2017) the report indicated that the estimated production of peppers in Ethiopia was 220,791ton from 97,712ha in green form and 118,514 ton of dry pepper from an area of 300,000ha.

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.*, 2015). 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, 2017). 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, 2017). 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 years both to increase the agricultural yield from already refined land and to permit the cultivation of what is currently known as marginal or unusable land due to the 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 in the irrigation until crop stress is evident, or using too little water, that can result in substantial yield loss of the crops. 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 information of the proper irrigation time and scheduling,

when to irrigate the crops and how much water to apply in irrigation, 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 (*Capsicum annum* L.) using CROPWAT computer model and to validate using a field trial.

MATERIALS 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 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. Field capacity and permanent wilting point of the sites are 32.92% and 19.03% for Ziqualla (Tsitsika small-scale irrigation scheme) and 32.51% and 16.28% for Abergelle (Bahir small-scale irrigation scheme).

Experimental setup

A field experiment to evaluate the CROPWAT model estimations was conducted during the 2014 and 2015. The experiment plot of 2.8m by 3m was used to test irrigation regimes. Hot pepper (*Capsicum annum* L. var. 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 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 (EIAR, 2004).

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 (I_3), (I_2), and (I_1) of optimum CROPWAT generated depth and irrigation interval of (5), (7), and (9) days (Table 1). The hand held watering cane was used to control the amount of water entering each furrow with the experimental plot (Yihun, 2015).
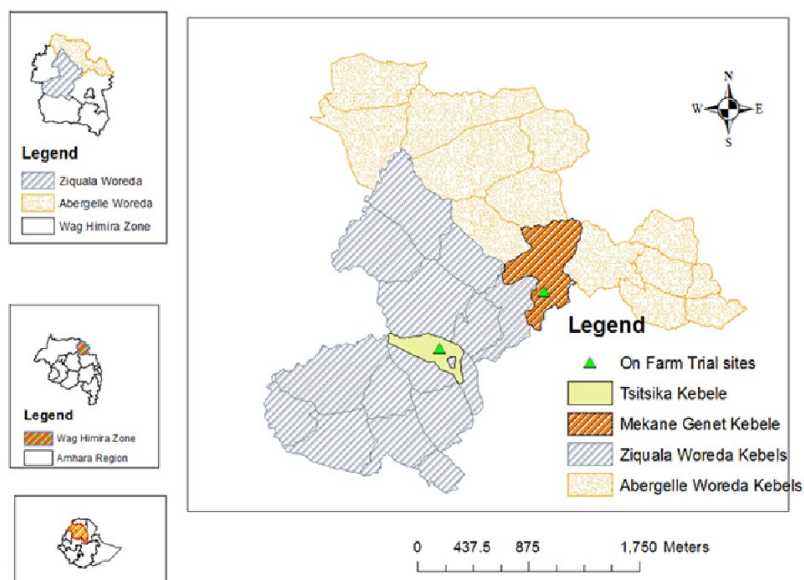
Figure1. *Location map of study area in Amhara Region, Ethiopia.*

Table 1. 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% (I$_3$) CROPWAT fixed depth (and optimal time of application at 5-day interval	455.3	445.7
125%(I$_3$) CROPWAT fixed depth and optimal time of application at 7-day interval	406.9	397.2
125% (I$_3$) CROPWAT fixed depth and optimal time of application at 9-day interval	343.2	338.1
100% (I$_2$) CROPWAT fixed depth and optimal time of application at 5-day interval	288.2	295.3
100%(I$_2$) CROPWAT fixed depth and optimal time of application at 7-day interval	284.8	279.4
100%(I$_2$) CROPWAT fixed depth and optimal time of application at 9-day interval	251.1	247.9
75%(I$_1$) CROPWAT fixed depth and optimal time of application at 5-day interval	225.7	229.1
75%(I$_1$) CROPWAT fixed depth and optimal time of application at 7-day interval	233.9	240.7
75%(I$_1$) CROPWAT fixed depth and optimal time of application at 9-day interval	222.9	218.2
Farmer's practice irrigation depth (Fd) and irrigation interval in days (Ff)	728.5	796.5

Determination of reference evapotranspiration

The reference evapotranspiration (ETo) on daily basis was calculated by applying the modified FAO Penman-Monteith equation based on daily record of climatic data (Allen *et al.*, 1998) using FAO CROPWAT software version 8.0. The input data for the CROPWAT software includes location i.e. altitude, latitude, and longitude of the meteorological station, daily values of maximum and minimum air temperatures, air humidity, sunshine duration, and wind speed were used from the nearest meteorological station located on the experimental field.

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).

$$ETc=ETo*Kc \qquad \text{Eq. (1)}$$

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:

$$IRn=ETc-Pe \qquad \text{Eq. (2)}$$

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.

$$Pe = 0.6 * P – 10/3 \text{ for P month} <= 70 \text{ mm or} \qquad \text{Eq. (3)}$$
$$Pe = 0.8 * P – 24/3 \text{ for P month} > 70 \text{ mm} \qquad \text{Eq. (4)}$$

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

The gross irrigation requirements account for losses of water incurred during conveyance and application to the field. This is expressed in terms of efficiencies when calculating project gross irrigation requirements from net irrigation requirements, as shown below:

IRg=IRn/Ea   Eq. (5)

Where, IRg= gross irrigation requirement(mm)
Ea= irrigation efficiency

Composite soil samples were collected from field plots and the soil textural analysis was done by hydrometer soil analysis method 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 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 diameter, 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

An interaction effect of depth and frequency on marketable yield, total yield, and water productivity on Ziqualla (Table 2). The result revealed that I_1 and I_2 CROPWAT generated depth using 5 and 7 days irrigation interval improved marketable yield, total yield and water productivity of hot pepper (*C. annum*) crop production, respectively. But farmers' irrigation scheduling and depth application practices are low yield gain because of more apply water and some of gap irrigation intervals cause water

logging, plants are not freely aired. In general, I_1 CROPWAT generated depth at 5 days irrigation interval provided a better yield and yield related components. The result in agreement with the finding of (Khalkho *et al.*, 2013) reported that yield and growth parameter data shown that the crop receiving irrigation at 60% available soil moisture offered the maximum green hot pepper yield of 9.1ton/ha (Yang *et al.*, 2017) stated that water deficit from reducing irrigation amounts to 1/3 to 2/3 of full irrigation during the development and middle 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 in line with (Serna Perez and Zegbe, 2012) described that hot pepper study, a water deficit of 15–45% can conserve 8–30% of irrigation water, and compared with full irrigation, a water deficit of 60% produced the highest percentage of marketable fruit but at similar yields as those under full irrigation in 2 of 3 years, consequently increasing irrigation water productivity. Associated with full irrigation, deficit irrigation can reduce irrigation depths by 20–50% and ultimately result in a higher water productivity (Dorji *et al.*, 2005, Gençoğlan *et al.*, 2006, Gonzalez-Dugo *et al.*, 2007, Yang *et al.*, 2018, Al-Ghobari and Dewidar, 2018; Abayomi *et al.*, 2012). Moreover, those studies I_1CROPWAT 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. This amount of irrigation water could be used to irrigate an additional irrigation land of 2.2ha with a yield benefit of 25.2 ton/ha of hot pepper (*C. annum*) crop production.

While observing variations among treatments, the only variation for the experiment was water application depth and time of application among treatments throughout the hot pepper growth stage. The variation in water amount applied each irrigation was attributed to the K_c value variations in the stages of crop growth. As it is observed from the experiment, crop water requirement was low at the initial stage, increased during the development stage, reached a maximum at the mid-season stage, and declined during the late-season stage.

Table 2. Interaction effects of depth and frequency on marketable yield, total yield, and water productivity in Ziqualla.

| Frequency | Total yield (ton/ha) | | | | Marketable yield (ton/ha) | | | | Water productivity (kg/m^3) | | | |
| | Depth | | | | Depth | | | | Depth | | | |
	I_1	I_2	I_3	F_d	I_1	I_2	I_3	F_d	I1	I_2	I_3	F_d
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, I_1=75% crop water requirement, I_2=100% crop water requirement, I_3=125% crop water requirement, F_d=farmer practice irrigation depth, F_f=farmer practice irrigation interval.

Table 3. Effects of depth and frequency on pod length, pod diameter, no. of pod per plant, plant height, canopy diameter and unmarketable yield at Ziqualla 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
I_1	9.06a	1.47a	18.78a	71.33a	39.34a	0.24a
I_2	8.80a	1.45a	20.15a	70.62a	38.97a	0.27a
I_3	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
F_p	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

Table 4. 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

(*P≤0.05*) *** Very highly significant, ** Very significant, * significant, [ns] none significant

Table 5. The interaction effects of depth and frequency on number of pod per plant, total yield, marketable yield and water productivity in Abergelle experimental site.

Frequency	No. of pod per plant				Total yield (ton/ha)				Marketable yield (ton/ha)				Water productivity (kg/m^3)			
	Depth				Depth				Depth				Depth			
	I_1	I_2	I_3	F_d	I_1	I_2	I_3	F_d	I_1	I_2	I_3	F_d	I_1	I_2	I_3	F_d
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, I_1= 75% crop water requirement, I_2=100% crop water requirement, I_3= 125% crop water requirement, F_d= Farmer practice irrigation depth, F+ = 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 (Table 3). The optimum application of I_1, I_2, 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 in line with (Delelegn, 2011) informed that hot pepper which obtained a better pod diameter and pod length using Mareko Fana at Jimma areas. Larger and wider hot

pepper pods are considered to be the best in quality and have better demand for fresh as well as dry pod use in Ethiopian markets (Beyene and David, 2007). It can be taken as a suggested I_1 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 2). 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 (*C. annum*).

Correlation analysis between yield parameters was tested using t-test as shown in Table 4. The result revealed a highly correlation coefficient (r≥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).

There was an interaction effect both in depth and irrigation frequency on a number of pods per plant, marketable yield, total yield, and water productivity in a situation of Abergelle (Table 5). The effect indicated that irrigation application of I_1 and I_2 CROP-WAT 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 were 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 2.8ton/ha in that order related to the farmer's irrigation application practices. In relationships of water productivity, irrigation application of CROPWAT generated depth I_1 and I_2 with 5 days irrigation interval, about 662m^3/ha amount of irrigation water was saved which would like to irrigate an additional lands of 0.29ha that produce 2.6ton/ha. The yield variance between the two application depths was 3.7ton/ha of hot pepper (*C. annum*) crop yield advantages by using I_1 CROP-WAT generated depth. In the same way, as compared to farmer irrigation practices, 5675m^3/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.

In irrigation studies, Zegbe-Dominguez *et al.* (2004) and 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.

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.

The correlation coefficient analysis such as indicated that marketable yield was significantly correlated (r≥0.9) with total yield, and also water productivity was significantly correlated through marketable yield and total yield (r≥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 6. Effects of depth and frequency on pod length, pod diameter, plant height, canopy diameter and the unmarketable yield of hot pepper (*C. annum*) in Abergelle.

Treatment	Pod length (cm)	Pod diameter (cm)	Plant height (cm)	Canopy diameter (cm)	Unmarketable yield (ton/ha)
Depth					
I_1	8.41a	0.80ab	69.90a	39.48a	0.31ab
I_2	8.21a	0.85a	69.02a	37.91ab	0.25b
I_3	8.24a	0.86a	68.95a	38.05ab	0.34a
F_d	7.41a	0.65b	68.00a	32.26b	0.33ab
LSD	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
F_f	7.41bc	0.65b	68.00a	32.26b	0.33ab
LSD	1.67	0.15	9.66	6.90	0.08
Cv (%)	15.28	13.94	10.49	13.68	19.72

Table 7. 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

(P≤0.05) *** Very highly significant, ** Very significant, * significant, [ns] none significant

Conclusion

The results of the experiment was conducted at Ziqualla, Tsitsika small-scale irrigation scheme, and Abergelle, Bahir small-scale irrigation scheme showed that research intervention was very important for improving crop production of hot pepper (*C. annum*) by saving a significant amount of water for irrigating the additional land. 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 I_1 and I_2 CROPWAT generated depth at 5 and 7 days irrigation interval provided a relatively significant and higher value in terms of many yield parameters including marketable yield and water productivity both on Ziqualla and Abergelle. Comparing with farmers' practice, I_1 CROPWAT generated depth at 5 days irrigation intervals saved irrigation water that would irrigate an additional land of about 2.2ha on Ziqualla, 2.4ha, on Abergelle. However, considering the economic advantage of water productivity between I_1 CROPWAT generated depth at 5 days irrigation interval and I_1 CROPWAT generated depth at 7 days irrigation interval, I_1 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. The main agricultural water management strategy for dry land and water scarcity areas like Wag-himra is primarily to improve the agricultural productivity and hence the income of the farmers by applying optimum amount of water and saving a significant amount of water for irrigation additional hot pepper crop land. Considering this, the irrigation application of I_1 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.

ACKNOWLEDGEMENT

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