Determination of Irrigation Regime for Hot Pepper in Dryland Areas of Wag- Himira North Eastern Amhara

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Abstract

Driven both by climate change and poor water management, droughts are becoming more frequent and

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). It is 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 the country 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 97,712ha in green form and 118,514 ton of dry pepper from an area of 300,000ha. The production of peppers in Ethiopia was 45,853.69 tons from 7,449.59 hectares in green form and 262,790.83 tons of dry pepper from an area of 142,795.16 hectares. Even though the average productivity of pepper at the national level in 2016 was 6.16 and 1.84 t ha^{-1}, yield reduction by 0.18 and 0.05 t ha^{-1} was observed for green and dry pepper from 2014-2016 cropping season, respectively (CSA, 2015).

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). However, the cumulative need for crop production due to the growing population in the world is demanding a rapid growth of irrigated agriculture throughout the world. As population rises and development calls for, the distributions of ground and surface water for the domestic, agriculture and industrial sectors augmented; as a result, the pressure on water resources strengthens. The increasing stress on freshwater resources transported about by ever rising demand for water is of thoughtful concern (Steduto *et al.*, 2017). Notwithstanding the increase in water use by subdivisions other than agriculture, irrigation carries on to be the main water user on a worldwide gauge. Irrigated agriculture consumes more than 70% of the water haggard from the rivers of the world and for the developing world; the proportion can reach 80% (Food and Nations, 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 Wag-Himira. 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 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).

In Wag-Himira Zone, Abergelle and Ziqualla woredas, irrigation scheduling and inadequate management of irrigation water has been an important limiting factors to pepper production. The farmers in general 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 activity was conducted with the objective of determining the net irrigation requirements and irrigation schedule for hot pepper using CROPWAT computer model and to validate using field trial.

Material and Methods

The study sites are located at 1414332N and 475070E Ziqualla; at 1425280N and 495749E Abergelle. The sites are characterized by clay textured soil. The particle size distribution of clay, silt, and sand is 41.29%, 29.92%, 28.79% at Ziqualla (Tsitsika small scale irrigation scheme) and 41.3%, 26.7%, 32% at Abergelle (Bahir small scale irrigation scheme). Field capacity and permanent wilting points 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).

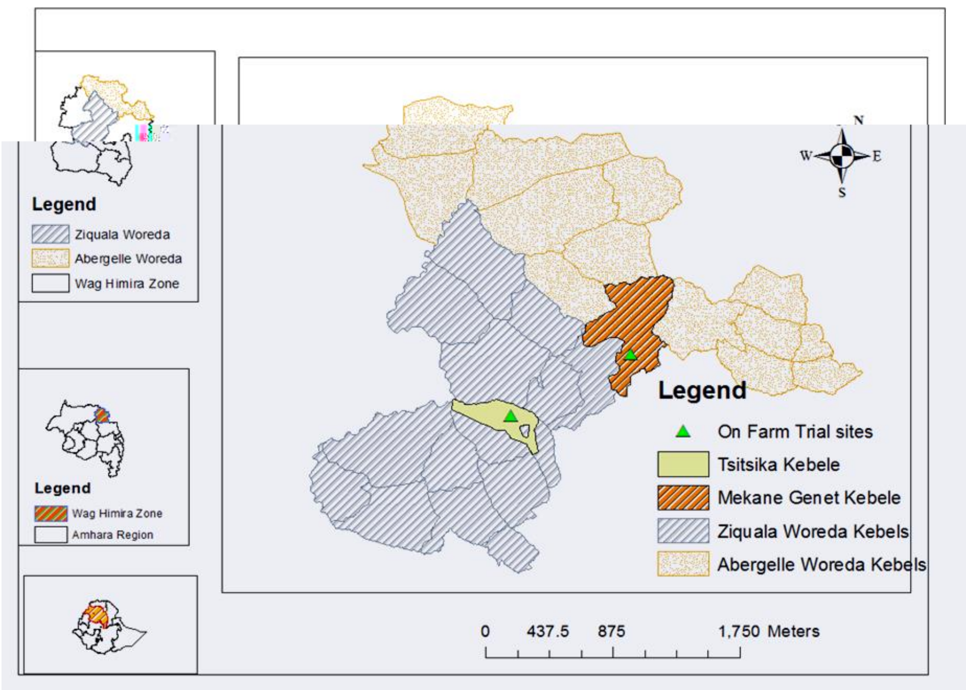

Figure 1. Location map of study areas

Determination of Crop Water Requirement using CROPWAT

Estimation of crop water requirement, net irrigation requirement, and schedule of the water application were carried out with inputs of soil, climatic and crop data using CROPWAT computer programmed. The model requires crop data such as crop type, planting date, duration of growth stage, maximum rooting depth, Kc values, depletion fraction and yield reduction coefficient and climatic data including maximum and minimum Temperature, rainfall, wind, sunshine hours, and relative humidity and soil type. Climatic data of the experimental sites were collected from neighboring stations like Tekez Bridge, Abiyadi, Gonder, and Lalibela and extrapolated using LocClim Software. For estimating the crop water requirement, given the required input data, the reference evapotranspiration was calculated first using the Penman-Monteith equation in the CROPWAT program (Allen *et al.*, 1998). 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. In addition, the representative soil sample collected from the field with core sampler 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 as indicated as follows. TAM=(FC-PWP)*D, Where, TAM=Total available moisture, FC=water content at field capacity, PWP=water content at a permanent wilting point below it cannot extract by plant roots, D=current root 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. The estimated crop water requirements were converted into the field irrigation water requirement. The net irrigation requirement was determined based on the equation. NIR=CWR Peff, Where, NIR=Net Irrigation Requirement (mm/period), CWR=Crop Water Requirement (mm/period), Peff=Effective Precipitation. The exact volume of water needed to fulfill the irrigation water requirement throughout the growing season was calculated using the equation below.

$$\text{Gross irrigation requirement(mm)} = \frac{\text{Net irrigation requirement(mm)}}{\text{Application efficiency(infraction)}}$$

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.

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

Experimental setup

A field experiment to verify CROPWAT model estimations was conducted in 2014 and 2015. The experiment plot of 2.8m by 3m was used to test irrigation regimes. Hot pepper (Marko fana variety) was selected as test crop. The selected Hot pepper variety has a growing period 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. The spacing was 70cm and 30cm between rows and plants, respectively. Blanket recommended fertilizer rate of DAP 100kg at transplanting and urea fertilizer of 100kg at half transplanting and half 45 days was applied in both experimental sites. Both diseases and weed infestation was 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, 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. 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 125%, 100%, and 75% of optimum CROPWAT generated depth and irrigation interval of 5, 7, and 9 days. Furrow irrigation was used for applying water at 60% application efficiency.

Data analysis

All the agronomic, yield and water productivity data 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

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% CROPWAT fixed depth and optimal time of application at 5 days interval	455.3	445.7
125% CROPWAT fixed depth and optimal time of application at 7 days interval	406.9	397.2
125% CROPWAT fixed depth and optimal time of application at 9 days interval	343.2	338.1
100 % CROPWAT fixed depth and optimal time of application at 5 days interval	288.2	295.3
100 % CROPWAT fixed depth and optimal time of application at 7 days interval	284.8	279.4
100 % CROPWAT fixed depth and optimal time of application at 9 days interval	251.1	247.9
75 % CROPWAT fixed depth and optimal time of application at 5 days interval	225.7	229.1
75 % CROPWAT fixed depth and optimal time of application at 7 days interval	233.9	240.7
75 % CROPWAT fixed depth and optimal time of application at 9 days interval	222.9	218.2
Farmers practice irrigation depth and irrigation interval in days (FP)	728.5	796.5

Result and Discussion

As shown in table 2, there was an interaction effect of depth and frequency on marketable yield, total yield, and water productivity at Ziqualla. The result reveals that 75% CROPWAT generated depth with 5 days interval gave marketable yield of 11220.5 kg ha^{-1}, total yield of 11458.6 kg ha^{-1}, and water productivity of 5.06 kg m^{-3}. Whereas, 100% CROPWAT generated depth with 7 days interval provided 11385.3 kg ha^{-1} marketable yield, 11619.2 kg ha^{-1} total yield, and 4.55 kg m^{-3} water productivity. There was statistically non-significance difference in marketable, total yields and water productivity between 75% and 100% water depth at 5 and 7 days interval respectively. In addition, 75% water depth with 5 days interval gave 5780.9 kg ha^{-1} and 100% water depth with 7 days gave interval gave 5945.6 kg ha-1 yield advantage over the irrigation practices. Moreover, there was statistically significant difference between 100% and 125% water depth at 5 days interval and 75% and 125% water depth at 7 days interval on marketable yield, total yield, and water productivity. In general, 75% depth at 5 days interval provided better yield.

The result in agreement with the finding of Khalkho *et al.* (2013) reported that yield and growth parameter data revealed that the crop receiving irrigation at 60% available soil moisture offered the maximum green hot pepper yield of 9145 kg/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 rigation, 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).

The irrigation application of 75%, 100% and 125% CROPWAT generated depth at 9 days interval; however, contributed the lowest marketable yield, total yield, and water productivity. 75% and 100% CROPWAT generated depth at 5 and 7days irrigation application intervals used about a total seasonal water amount of 225.7mm (2257m^3/ha) and 284.8mm (2848m^3/ha) hot pepper crops in Ziqualla respectively. However, irrigation application of 100% application depth at 5 days interval presented 9085.1kg/ha of marketable yields that results in 3.85kg/m^3 of water productivity by using 2882m^3/ha of water. The irrigation scheduling of the farmers' practice furnished 5711.1kg/ha yields and 1.64kg/m^3 of water productivity by using 7285m^3/ha amount of water. Compared that the water productivity of 75% and 100% application depth at 5 days irrigation interval, an amount of 625m^3/ha water was saved by applying 75% irrigation generated depth at 5 days interval. This could be used for irrigating an additional land of 0.28 ha.

This 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. Compared with full irrigation, deficit irrigation can reduce irrigation depths by 20 50% and ultimately result in a higher water productivity (Dorji *et al.*, 2005; G *et al.*, 2006; Gonzalez-Dugo *et al.*, 2007; Yang *et al.*, 2018; Al-Ghobari and Dewidar, 2018; Abayomi *et al.*, 2012). Likewise, related the irrigation application of 100% and 125% at 7days interval each saved 1221m^3/ha amount of water, which could irrigate additional land of 0.42ha. Moreover, in interval and 100% depth at 7days irrigation interval saved 5028m^3/ha and 4437m^3/ha amount of water, correspondingly. This could be used to irrigate an additional land of 2.2ha and 1.5ha with a yield benefit of 25207kg/ha and 17428 kg/ha of hot pepper crop production, respectively.

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 to 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. As displayed in table 3 there were non-interaction effects in both depth and frequency on pod length, pod diameter, number of pods per plant, plant height, canopy diameter and unmarketable yield at Ziqualla. The optimum application of 75%, 100%, 125% CROPWAT generated depth had better pod length, pod diameter and a number of pods per plant compared with irrigation scheduling of farmers' practice. However, irrigation application of 75%, 100% and 125% water depth did not show significant difference both in plant height and unmarketable yield compared with farmers' practice.

Table 2. Interaction effects of depth and frequency on marketable yield, total yield and water productivity at Ziqualla (Tsitsika irrigation scheme).

	Total yield(kg/ha)				Marketable yield(kg/ha)				Water productivity(kg/m^3)			
	Depth				Depth				Depth			
Frequency	75%	100%	125%	FP	75%	100%	125%	FP	75%	100%	125%	FP
5	11458.6	9331.4	9204.4		11220.6	9085.1	8912.5		5.06	3.85	2.63	
7	9095.8	11619.2	9115.2		8861.4	11385.3	8868.8		2.86	4.55	2.87	
9	3152.6	3102.0	3406.3		2886.0	2751.2	3145.6		1.82	1.56	1.33	
FP				5711.1				5439.6				1.64
LSD	974.7				1015.1				0.57			
Cv (%)	10.09				10.13				15.21			

Irrigation application of 75% and 100% water depth presented the highest canopy diameter of 39.34 and 38.97cm, respectively while125% application depth and the irrigation schedule of the

m, respectively. Moreover, the table also showed that there was a significant difference between the application of 75% and 100% CROPWAT generated depth associated with 125% and farmers' scheduling in terms of canopy diameter. Considering the interval of the irrigation application, statistically, there was a non-significance difference in terms of pod length, pod diameter, number of pods per plant, canopy diameter, and unmarketable yield for 5 and 7 days interval. Likewise, there was a non-significance difference between 9 days and farmers' scheduling on pod diameter, number of pods

irrigation practices contributed the lowest pod length of 6.42 cm whereas irrigation application with 5, 7 and 9 days irrigation interval had 9.4cm, 8.96cm and 8.42cm, respectively. This result is in line with Delelegn (2011) informed that hot pepper which obtained a better pod diameter of 1.68cm and pod length 8.01cm using Mareko fana variety 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).

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.

Treatment	Pod length (cm)	Pod diameter (cm)	No of pod per plant	Plant height (cm)	Canopy diameter (cm)	Unmarketable yield (kg/ha)
Depth						
75%	9.06a	1.47a	18.78a	71.33a	39.34a	242.98a
100%	8.80a	1.45a	20.15a	70.62a	38.97a	276.95a
125%	8.92a	1.41a	19.65a	69.07a	38.01ab	266.34a
FP	6.42b	1.18b	13.96b	64.30a	34.56b	271.43a
LSD	1.97	0.19	3.15	9.95	3.67	95.04
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	255.33a
7 days	8.96a	1.45a	22.36a	71.82ab	42.44a	238.20a
9 days	8.42a	1.37ab	12.37b	62.90b	31.60b	271.43a
FP	6.42b	1.18b	13.96b	64.30b	34.56b	292.74a
LSD	1.97	0.19	3.15	9.95	3.67	95.04
Cv (%)	17.09	10.57	12.47	10.71	7.18	27.14

As described in the above and presented in table 2, it can be taken as a suggested 75% CROPWAT generated a depth and irrigation application of 5 days interval offered the highest value for the yield and yield related parameters in case of Ziqualla. 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.

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

Table 4. Correlation coefficient of different parameter (number of pods per plant, marketable yield, unmarketable yield, total yield and water productivity) from the study data.

parameters	number of pods per plant	marketable yield	unmarketable yield	total yield	water productivity
number of pods 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

By way of presented in table 5, 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. The effect indicated that irrigation application of 75% and 100% CROPWAT generated depth with 5 and 7 days interval were recorded the highest pods per plant with 19.6 and 20.0, marketable yield, 8855.6kg/ha and 8653.9kg/ha, total yield, 9215.9kg/ha and 8905.0kg/ha, water productivity, 4.10kg/m^3 and 4.09kg/m^3 respectively. These results were statistically significant pods per plant, marketable yield, total yield, water productivity compared with other treatments; on the other hand, there was a non-significant difference between them. They had a yield enhancement of 3123.9kg/ha and 2813.0kg/ha in that order related to the

CROPWAT generated depth at 9 days irrigation interval and farmer practices irrigation scheduling had the lowest water productivity, total and marketable yield.

In relationships of water productivity, irrigation application of 75% and 100% CROPWAT generated depth with 5days irrigation interval in seasonal irrigation water requirement of hot pepper was 229.1mm and 295.3mm at Abergelle correspondingly. Whereas, associating that 75% and 100% irrigation application depth through 5 days interval, about 662m^3/ha amount of water was saved which would like to irrigate an additional land of 0.29ha that produce 2662.9kg/ha and the yield variance between the two application depth was 3784.4kg/ha of hot pepper crop yield advantages by using 75% CROPWAT generated depth. 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. In the same way as compared to farmer irrigation scheduling practices, 5675m^3/ha amount of irrigation water, which could confine to irrigate another land of 2.4ha and 22,118kg/ha the yield gain of hot pepper production in Abergelle areas.

As given away in table 6, there were not at all interaction effects in both depth and frequency on pod length, pod diameter, plant height, canopy diameter and unmarketable yield of hot pepper crops trendy instance of Abergelle. However, irrigation application using CROPWAT generated depth of 75%, 100%, and 125% had better pod diameter, canopy diameter is proportional to farmers' irrigation request practices. Since the irrigation interval point of view, the table exhibited that there was the non-significance difference between irrigation application of 5 and 7 days in terms of pod length, pod diameter, plant height, and canopy diameter. Nonetheless, there

Table 5. The interaction effects of depth and frequency on No of pod per plant, total yield, marketable yield and water productivity in Abergelle (Bahir small scale irrigation scheme).

	No of pod per plant				Total yield (kg/ha)				Marketable yield(kg/ha)				Water productivity(kg/m^3)			
	Depth				Depth				Depth				Depth			
Frequency	75%	100%	125%	FP	75%	100%	125%	FP	75%	100%	125%	FP	75%	100%	125%	FP
5 days	19.6	17.6	17.3		9215.9	8094.4	7650.7		8855.6	7836.5	7206.3		4.10	3.14	2.00	
7 days	13.9	20.0	18.7		7822.2	8905.0	7919.0		7580.1	8653.9	7595.2		2.92	4.09	2.73	
9 days	10.4	12.9	14.4		3010.1	2843.6	3006.5		2677.7	2578.5	2749.2		1.91	1.29	1.19	
FP				13.0				6092.0				5758.2				0.88
LSD	2.30				718.33				728.18				0.35			
Cv (%)	10.96				8.35				8.89				10.97			

FP=farmer irrigation scheduling practice

Table 6. Effects of depth and frequency on pod length, pod diameter, plant height, canopy diameter and unmarketable yield on Abergelle.

Treatment	Pod length (cm)	Pod diameter (cm)	Plant height (cm)	Canopy diameter (cm)	Unmarketable yield (kg/ha)
Depth					
75%	8.41a	0.80ab	69.90a	39.48a	311.62ab
100%	8.21a	0.85a	69.02a	37.91ab	258.07b
125%	8.24a	0.86a	68.95a	38.05ab	341.85a
FP	7.41a	0.65b	68.00a	32.26b	333.58ab
LSD	1.67	0.15	9.66	6.90	80.56
Cv (%)	15.28	13.94	10.49	13.68	19.72
Frequency					
5 days	9.46a	0.93a	72.22a	41.82a	354.23a
7 days	8.83ab	0.90a	70.87a	41.65a	272.38b
9 days	6.58c	0.67b	64.77a	31.97b	284.93ab
FP	7.41bc	0.65b	68.00a	32.26b	333.58ab
LSD	1.67	0.15	9.66	6.90	80.56
Cv (%)	15.28	13.94	10.49	13.68	19.72

FP=farmer irrigation scheduling practice,

The correlation coefficient analysis such as revealed in Table 7 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. 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 7. Correlation coefficient of different parameters (number of pods per plant, marketable yield, unmarketable yield, total yield and water productivity) from the study data.

parameters	number of pods per plant	marketable yield	unmarketable yield	total yield	water productivity
number of pods 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*

Conclusions and Recommendations

The results of the experiment at both locations indicated the importance of research interventions to improve hot pepper production by saving a significant amount of water for irrigating additional land. Application of irrigation depth at specific irrigation interval has shown a significant effect on yield and water productivity when compared with farmers' scheduling practices. Irrigation application of 75% and 100% CROPWAT generated depth at 5 and 7 days irrigation intervals provided a relatively significant and higher value in terms of marketable yield, total yield and water productivity both at Ziqualla and Abergelle. Comparing with the farmers' practices, 75% depth at 5 days interval as well as 100% depth at 7 days interval saved irrigation water that would irrigate an additional land of about 2.2 ha and 1.5 ha at Ziqualla, and 2.4 ha and 1.8 ha at Abergelle, respectively. However, in addition to saving 25% irrigation water without yield penalty, 75 % generated depth at 5 days gave 5781 kg ha^{-1} marketable yield advantage and 3.42 kg m^{-3} water productivity at Ziqualla and 3098 kg ha^{-1} marketable yield and 3.1 kg m^{-3} water productivity at Abregelle over the farmers practices. The main agricultural water management strategy for dry land and water scarce areas like Wag Himira is primarily to improve the agricultural productivity and hence improve the income of the farmers by applying optimum amount of water and saving significant amount of water to cultivate additional cropland by the saved irrigation water. Considering this, application of 75% CROPWAT generated depth at 5 days interval was found economically feasible and is recommended to be used by the farmers and other water users in Ziqualla and Abergelle woreda and other similar agro-ecologies. Furthermore, further research on fertilizer rate for hot pepper under irrigation is suggested.

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