Research Article

Evaluation and Demonstration of Irrigation Regime on Hot Pepper (*Capsicum Annuum L.*) in Benna-Tsemay Woreda, Southern Ethiopia

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A field experiment was conducted at Enchet kebele in Bennatsemay woreda Southern Ethiopia for two consecutive years during (2017 and 2018) in order to determine the optimum irrigation scheduling and water use efficiency of hot pepper under a conventional furrow irrigation system. The experimental design of treatments was laid out in randomized complete block design (RCBD). The trial has four levels of treatments (125% MAD, 100% MAD, 75% MAD and farmers practice).The experimental result shows that highest total yield was obtained from 125% MAD (23.15 ton/ha) as compared to other treatments; 100% MAD (18.97 ton/ha), 75% MAD (14.47 ton/ha) and farmer practice (11.63 ton/ha). The result indicated that, total yield of hot pepper was decreased with decreasing applied irrigation water. The highest water use efficiency (37 kg/ha-mm^{-1}) was obtained from treatment level of 125% MAD and lowest water use efficiency (27.52kg/ha-mm^{-1}) was obtained from farmer practice. Therefore, application of 125% MAD level was appropriate to increase economic yield of hot pepper and water use efficiency in the area. But, in water scarce areas like Benna-Tsemay woreda and other areas applying the recommended fraction (100% MAD) of crop water requirement is advisable with a minimum reduction of yield.

Key Words: *Irrigation Regime, Hot Pepper, Water Use Efficiency, Allowable Depletion*

INTRODUCTION

Irrigation is the most significant input in agricultural activities to improve the yields. Throughout the world, about 70% of available water resources are allocated to agricultural activities, especially to irrigation. Improving water use efficiencies are an important strategy for addressing future water scarcity problem particularly in arid and semi-arid regions (Mdemu *et al.* 2008). Today, it is almost impossible to increase the cultivated lands, therefore researches have to be done to improve unit area-yields to increase the total yields. Hot pepper is a high value cash crop, of which cultivation is confined to warm and semi-arid regions of the world, where water is often a limiting factor for crop production ((Dimitrov and Ovtcharrova, 1995). A shallow root system high stomata density, a large transpiring leaf surface and elevated stomata openings, make hot pepper plants susceptible to water stress (Delfine *et al.,* 2000). The conventional solution to water shortages has been irrigation water management. So, due to competing demands for irrigation

water by farmers as well as other private sectors the only option was irrigation scheduling. Irrigation scheduling (amount and timing) is the key issue to get the highest yields per unit area. Plant water consumption is the essential parameter of irrigation scheduling works and it may vary based on climate factors and plant growth stages. Thus, plant water consumption values should separately be determined for experimental area and such a case is especially significant in arid and semi-arid regions. Therefore the general objective of this study was to evaluate the irrigation regime on yield and water use efficiency of hot pepper at different irrigation water application levels.

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MATERIALS AND METHODS

Description of Study Area

A field experiment was conducted for two consecutive years during (2017 and 2018 G.C) at Enchete Kebele in Bennatsemay woreda in South Omo Zone. It was geographically located 05° 21'36'' N and 36° 59'56'' E with an elevation of 580 m.a.s.l. The experimental sites were agro- ecologically arid and semi-arid with mean monthly maximum and minimum temperature of 38°C and 18°C, respectively and low and erratic rainfall pattern with an average annual rainfall of 200-578 mm.

Figure 1: Map of Study Area
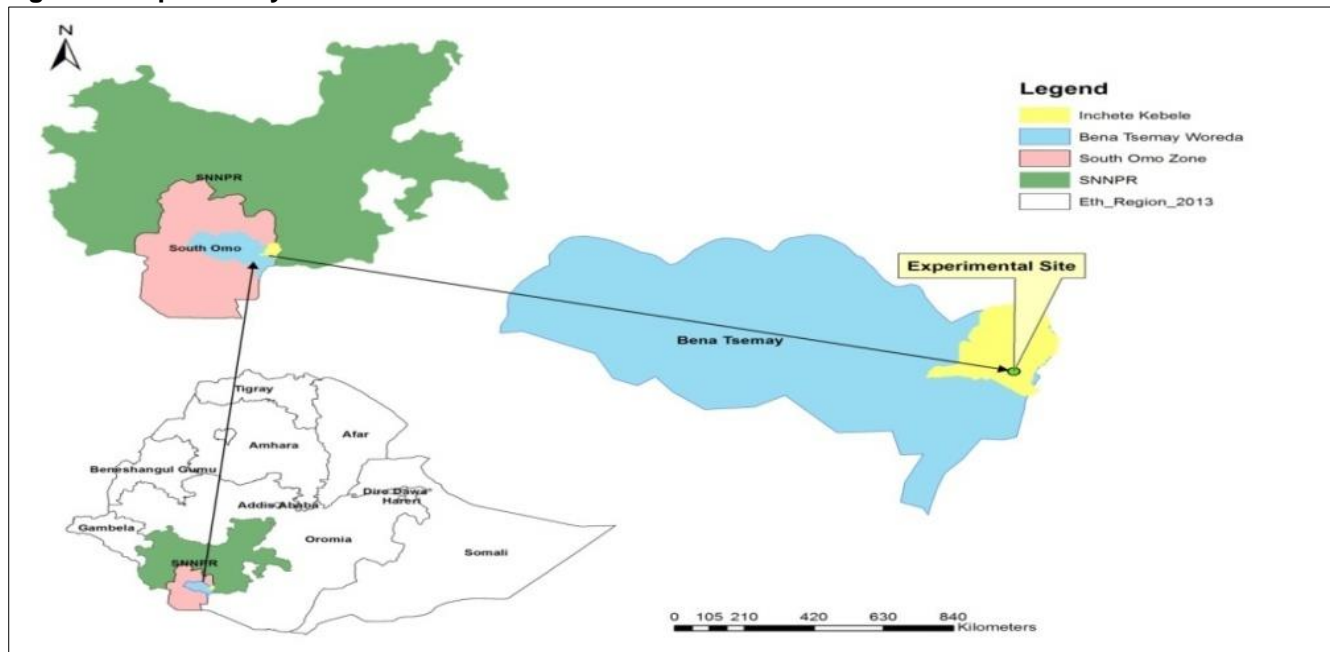
Soil Physical and Chemical Properties

The soil of the experimental site is classified as clay soil. Some physical and chemical properties of the experimental soil are presented in Table 1. The study site soil has average bulk density of 1.23 g/cm^3, pH of 8.4 and electrical conductivity of 0.2 ds/m.

Experimental Design

The experiment was laid out in randomized complete block design with four replications of four level treatments. The treatment was conducted under furrow irrigation method. The amount of irrigation water to be applied at each irrigation application was measured using Parshall flume. The treatments were 125% of allowable soil moisture depletion (ASMD), l00% of allowable soil moisture depletion (ASMD) or full level, 75% of allowable soil moisture depletion (ASMD) and the fourth was farmer practices (FP). The experimental field was divided into 16 plots and each plot size was 4m by 5m dimension. The space between rows and the plants were 70 cm and 30 cm, respectively.

Crop Data

Maximum effective root zone depth (Rz) of hot pepper ranges between 0.5 - 1 m and has allowable soil water depletion fraction (P) of 0.25 (Andreas *et al.,* 2002). Hot Pepper average Kc (crop coefficient) would be taken after adjustments have been made for initial, mid and late season stage to be 0.35, 1.05 and 0.95, respectively (Allen *et al.,* 1998). Yield data like marketable yield, unmarketable yield, total yield and other agronomic parameters were measured in the field.

Crop Water Determination

The crop water requirement refers to the amount of water that needs to be supplied, while crop evapotranspiration refers to the amount of water that is lost through evapotranspiration (Allen *et al.,* 1998). For the determination of crop water requirement, the effect of climate on crop water requirement, which is the reference crop evapotranspiration (ETo) and the effect of crop coefficient (Kc) are important (Doorenbos and pruitt, 1977). The long term and daily climate data such as maximum and minimum air temperature, relative humidity, wind speed, sunshine hours, and rainfall data of the study area was collected from National Meteorological Agency, Hawassa Branch Directorate in order to determine

reference evapotranspiration by using FAO CropWAT software version 8.0 (Allen *et al.*, 1998).

$$ETc = (ETo \times Kc) ----------------(2.1)$$

Where, ETc = crop evapotranspiration, Kc = crop coefficient, ETo = reference evapotranspiration

Irrigation Water Management

The total available water (TAW), stored in a unit volume of soil was determined by the expression:

$$TAW = \frac{FC - PWP}{100} * Bd * Rz ----------- (2.2)$$

Where, TAW is total available water in **mm/m**, FC is field capacity and PWP is permanent welting point in percent (%) on weight basis, Bd is bulk density and Rz is maximum root depth.

The depth of irrigation supplied at any time can be obtained from the equation:

$$Inet(mm) = (ETc_{mm} - Peff_{mm}) -----------(2.3)$$

Inet = net irrigation and Peff = effective rain fall

The gross irrigation (GI) requirement was obtained from the expression:

$$GI = \frac{Inet}{Ea} ------------------(2.4)$$

Ea = application efficiency of the furrows (60%)

The time required to deliver the desired depth of water into each furrow was calculated using:

$$t = \frac{d * l * dg}{6Q} ------------------(2.5)$$

Where: dg = gross depth of water applied (cm), t = application time (min), l = furrow length in (m), w = furrow spacing in (m), and Q = flow rate (discharge) (l/s)

The amount of irrigation water to be applied at each irrigation application was measured using Parshall flume.

Data Collection

The main climatic data used to determine ET_O and ETc was acquired from the Southern National Meteorological Agency of Ethiopia. Data obtained through field and laboratory analysis were soil data, bulky density, irrigation water, infiltration rate and agronomic data. Amount of applied water per each irrigation event was measured using calibrated Parshall flume. Five random plants per plot excluding the border rows and border plants in the central rows were taken as a sample to record yield and yield component. The amount of bulb produced was collected and weighed from the four central rows of each plot to avoid boarder effects.

Crop Water Use Efficiency (CWUE)

CWUE is the yield harvested in kilogram per ha-mm of total water used. It was calculated using formula as the ratio of crop yield to the amount of water consumptively used by the crop (Ibragimov *et al.*, 2007):

$$CWUE = \frac{Y}{ETc} ------------------------------------(2.6)$$

Where: CWUE = crop water use efficiency (kg/m^3)
   Y = yield in kg ha^{-1} and
   ETc = is crop evapotranspiration (mm)

Statistical Analysis

The collected data were analyzed using Statistical Agricultural Software (SAS 9.0) and least significance difference (LSD) was employed to see a mean difference between treatments and the data collected was statistically analyzed following the standard procedures applicable for RCBD with single factor. The treatment means that were different at 5% levels of significance were separated using LSD test.

RESULTS AND DISCUSSION

Physical and Chemical Properties of Soil

According to the data in the table below, an average composition of sand, silt and clay percentages were 60.33%, 23% and 10.33%, respectively. Thus, according to the USDA soil textural classification the experimental site soil was classified as sandy loam. The experimental site soil sample was collected by core sampler on 0 – 5 cm depth base and its bulky density was conducted under oven dry at 105^0 for 24 hrs. The top soil surface had slightly lower bulk density (1.26) than the subsurface (1.31). This could be because of slight decrease of organic matter with depth and compaction due to the weight of the overlying soil layer (Brady and Weil, 2002).

In general, the average soil bulk density (1.28 g/cm^3) is below the critical threshold level (1.4 g/cm^3) and was suitable for crop root growth. The average pH of the experimental soil was 8.4. This shows that the pH of the site is nearly neutral and suitable for crop production (Adinew, 2005). The ECe of the experimental site soil was 0.2 dSm^{-1}. According to Hazelton and Murphy (2007) soils having the ECe less than 4dSm^{-1} are considered as non-saline and suitable for vegetable production. The average organic matter content of the soil was about 2.7%. As cited

in Staney and Yerima (1992), the organic matter content of the soil is of medium class. The average infiltration rate of the experimental area was found to be 7.2 cm/hr.

According to Israelsen and Hansen (1962) the soil of experimental area was moderately rapid.

Table 1: Soil physical and chemical characteristics of the experimental area

Depth (cm)	Sand (%)	Clay (%)	Silt (%)	Texture class	OM %	pH	EC (ds/m)	BD (g cm^{-3})	FC (%)	PWP (%)	TAW (mm/cm)
(0-20)	59	12	29	Sandy Loam	2.7	8.4	0.31	1.26	29.3	12.8	33.1
(20-40)	68	13	19	Sandy Loam	2.7	8.4	0.18	1.28	28.1	12.5	31.3
(40-60)	54	14	32	Sandy Loam	2.7	8.4	0.11	1.31	26.0	10.7	30.6
Average	60.3	10.3	23		2.7	8.4	0.2	1.28	27.8	12.0	31.7

Irrigation Water Requirements of Hot Pepper

Water requirement of hot pepper was determined from climate data acquired from the regional   metrological station by using CropWAT 8.0 model. Gross irrigation depth was estimated considering field irrigation application efficiency of 60%. Accordingly, net irrigation depths, gross irrigation depth and time of watering based on three days, four days, five days average irrigation interval and farmer practice was evaluated and water once in the week were applied in the field.

Table 2: Mean combined values of yield and yield parameters of hot pepper

Treatment	PH (cm)	NB	FL (cm)	FD (cm)	MY (t/ha)	UMY (t/ha)	TY (t/ha)
125%MAD	81.15[a]	35[a]	11.21[a]	11.21[a]	20.31[a]	2.84[a]	23.15[a]
100%MAD	79.55[ba]	30[b]	10.43[b]	10.43[b]	16.34[b]	2.64[ab]	18.97[b]
75%MAD	76.31[ba]	26[c]	10.05[b]	10.01[b]	12.02[c]	2.45[ab]	14.47[c]
FP	73.06[b]	24[c]	8.77[c]	8.77[c]	9.54[d]	2.09[b]	11.63[d]
CV	9.45	23.75	15.68	7.17	8.5	26.69	7.51
LSD	7.55	7.07	0.23	0.75	1.28	0.69	1.32

Means with the same letter (s) are not significantly different at P ≤ 0.05; LSD = least significant difference; CV -Coefficient of Variation. PH= plant height, NB = number of branch, FL = Fruit length, FD= fruit diameter, MY = marketable yield, UMY = unmarketable yield and TY = total yield.

The result in table 2 indicated that plant height was significantly affected by different soil moisture depletion level. However, non-significant difference observed in height among plants grown under the 100% MAD (79.55 cm) and 75% MAD (76.31 cm). Among the applied irrigation soil moisture levels, 125% MAD (81.15 cm) gave significantly the highest plant height while the shortest plant height was recorded from farmers practice (73.06 cm). From this finding it is clearly seen that as the soil moisture level decreased the plant height decreased. This finding is in agreement with the findings of Aklilu (2009) and Takele (2009) reported that, the plant height of hot pepper decreased with decreased irrigation level.

The analysis of variance showed that moisture levels and irrigation frequency were significantly affected by total fresh fruit yield of hot pepper. The highest total fresh fruit yield was obtained from 125% MAD (23.15 ton/ha) where as the lowest marketable fruit yield was obtained from treatment of farmers practice (11.63 ton/ha). For high yields, an adequate water supply and relatively moist soils are required during the entire growing season. The reduction in water supply during the growing period, in general, has an adverse effect on yield.

Table 3: Applied water, water use efficiency, water saved and percent yield reduction of hot pepper under irrigation regime

Treatment	AW (mm)	Yield (kg/ha)	WUE (kg/hamm^{-1})	Water saved (mm)	Yield reduction (%)
125%MAD	552.0	20310	36.79	0.0	0.0
100%MAD	441.6	16340	37.00	110.4	19.3

75%MAD	331.2	12020	36.29	220.8	40.0
Farmers Practice	346.67	9540	27.52	205.3	52.2

AW= Applied Water, CWUE = Crop water use efficiency.

The analyzed result in table 3 shows that the highest WUE was obtained in 100% MAD (37.00 kg/hamm^{-1}) irrigation level while the lowest WUE was obtained in farmer practice of irrigation level (27.52 kg/hamm^{-1}). The results of this study were in agreement with Gençoglan and Yazar (1999), who reported that WUE values decreased with increasing soil moisture levels. This indicates that the farmer in the area used under irrigation system (below crop water demand) and this might be caused high yield reduction. On the other hand, from the table 3 above large amount of water was saved under 75% MAD with high yield reduction when compared to other treatments except farmer practices.

CONCLUSION AND RECOMMENDATION

This study showed that managing the soil moisture content at different depletion levels had influenced the production and water productivity of hot pepper. The highest yield was obtained from increasing the soil moisture depletion level with 25% over the recommendation in contrast the lowest fresh hot pepper yield was acquired from traditional method of water application. In the other hand reducing the soil moisture depletion level by 25% from the recommended fraction (0.25) resulted in relatively optimum yield. The highest water productivity and minimum yield reduction were acquired from the soil moisture depletion level with 100% MAD in the area while, the lowest water productivity and highest yield reduction were obtained from farmer practice. The highest water productivity and relatively optimum yield reduction were obtained from the recommended fraction (75% MAD) while the high water productivity and no yield reduction were obtained from the recommended fraction (125% MAD). Therefore, in areas where sufficient availability of irrigation water, applying the soil moisture depletion level with 25% over the recommendation through the growing season was recommended. But, in water scarce areas like Bena-Tsemay woreda and other water scarce areas applying the recommended fraction (100% MAD) of crop water requirement is advisable with a minimum reduction of yield.

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