



Research Article

Effect of irrigation scheduling on hot pepper yield and water productivity in Tembaro special district southern Ethiopia

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Abstract

The rising competition for irrigation water necessitates the adoption of scheduling measures that promote efficient water application methods. Irrigation scheduling is becoming more popular as a means of reducing extra water consumption without negatively affecting output in the context of improving water use productivity. This study was aimed at the effect of irrigation scheduling on the pod yield of hot pepper and water productivity. The result revealed that irrigation scheduling technology significantly affects the yield of hot pepper and water productivity. Maximum pod yield (96.67Qt/ha) was acquired at 100% of Maximum Allowable Depletion (MAD) and minimum pod yield practice (88.00Qt/ha) obtained from farmers' practices. Higher (2.21kg/m³) and lower (1.62kg/m³) water productivity were acquired at 100%MAD and farmer practices respectively. Economic analysis indicates that, 474,518ETB/ha and 419,300ETB/ha acquired at 100%MAD and Farmers practice respectively. Irrigation scheduling technology manages scarce water resource, time and increases pod yield and water productivity. Therefore, it was recommended irrigating hot pepper in a fixed intervals of five days at the initial period and seven days for the rest of three growing periods to save irrigation water, labor costs, increase economic income, pod yield and water productivity.

1. Introduction

The farming sector is under increasing pressure to efficiently utilize existing water for irrigation to produce additional food to meet the growing global population due to increased water demand from factories and municipal sectors [1]. The purpose of agricultural water management is to minimize losses of water and maximize transpiration, which is the beneficial loss of water due to its direct link to dry matter production [2]. Irrigation scheduling technology has conventionally aimed to achieve an optimum water supply for productivity, with soil water content being maintained close to field capacity. In many ways, irrigation scheduling can be regarded as a mature research field which has moved from

innovative science into the refinement of existing practical applications. Nevertheless, in recent years there has been a wide range of proposed novel approaches to irrigation scheduling that have not yet been widely adopted; many of these are based on sensing the plant response to water deficits rather than sensing the soil moisture status directly [3]. Irrigation scheduling methods are based on two approaches, soil measurements and crop monitoring [4]. Irrigation scheduling involves determining both the timing of irrigation and the quantity of water to apply. Efficient scheduling of irrigation water applications gives the highest return for the least amount of water [5]. Therefore, this study was

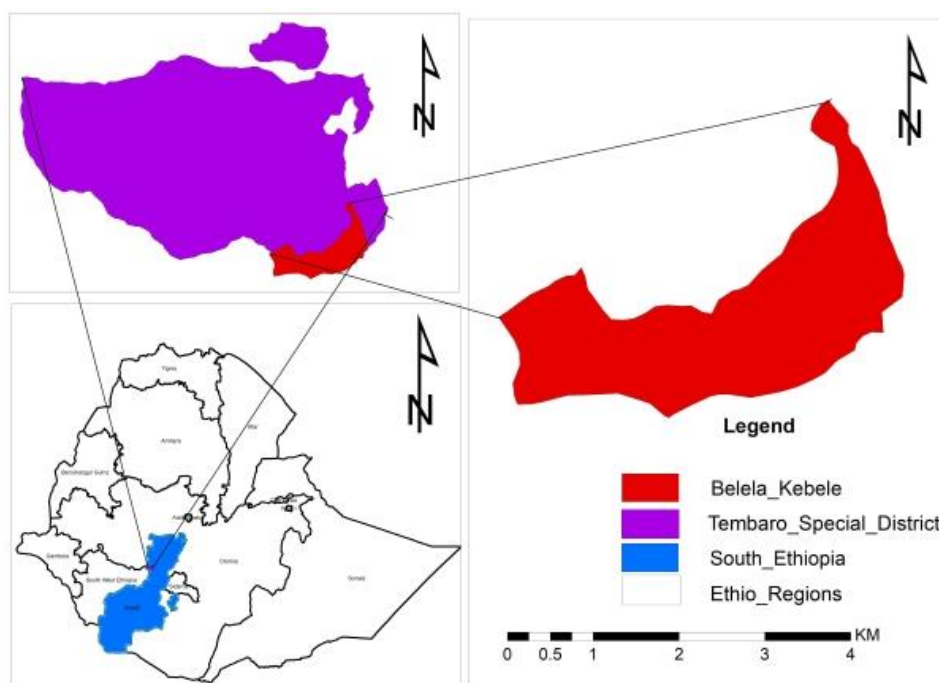


Figure 1. Map of the study area

conducted to evaluate, demonstrate, and assess the effect of irrigation regime on hot pepper yield and water productivity.

2. Materials and methods

2.1. Description of the study site

The study was conducted at the Gordena Irrigation Scheme, in Belela Kebele, Tembaro Special District, Kembata Tembaro Zone, Southern Ethiopia (Fig 1). The scheme was constructed by the Participatory Small Scale Irrigation Development Program (PASIDP-II) and managed by the community. The experimental research was done in collaboration with Participatory Small Scale Irrigation Program-II and Southern Agricultural Institute. The study site was geographically located at a latitude of 07.217° , and a longitude of 037.595° E with an elevation of 1459 m. a. m. s. 1 in low land agro-ecology. The irrigation scheduling technology on the hot pepper (local variety) was selected for the demonstration according to farmers' selection and previous habit, quantity, agro ecological suitability and practices.

2.2. Experimental design and treatments

The design of the experimental layout is laid in Randomized Complete Block Design (RCBD). The treatments were 100%MAD and farmers practice (farmers irrigating with community schedule) and

farmers were used as replications. Spacing between plot to plot, plant to plant and furrow to furrow were 100cm, 30cm and 70cm respectively. The recommended fertilizer was NPSB (200kg/ha) and Urea (100kg/ha) for hot pepper (Local varieties) and Urea was applied during the first weeding based regional recommendation for the crop.

2.3. Soil physical and chemical properties

Soil physical, and chemical properties affect many processes in the soil that make it suitable for agricultural practices and other purposes. Soil texture can have a profound effect on many other properties and is considered among the most important physical properties. The textural class of the soil is clay loam and its bulk density is $1.04\text{g}/\text{cm}^3$ as shown in Table 1. Well drained loamy soil is one the optimal ecological requirements for pepper production.

The pH value of the soil was (5.59) which is found under range (5.5-7) for optimal ecological requirement of the pepper [6]. The electric conductivity of the soil (ECe) value was (0.64dS/m), as illustrated in Table 2 which was, below a (1.5 dS/m) threshold value for soil salinity for the hot pepper grown worldwide [7].

2.4. Crop water requirement

This is the total amount of water needed to grow a given crop from sowing/planting to maturity [8]. Crop water requirements are expressed usually in mm/day,

Table 1. Soil physical properties

Soil Physical parameters				Bd (g/cm ³)	FC (%)	PWP (%)
Sand	Silt	Clay	Textural class			
34	26	40	Clay Loam	1.04	38	25

Table 2. Soil chemical properties

Chemical Parameters	pH	ECe (dS/m)	OM (%)	OC (%)
Values	5.59	0.64	3.89	2.26

mm/month or mm/season and they are used for the management purposes: in the estimation of irrigation water requirements, irrigation scheduling and water delivery scheduling [9]. To determine crop water requirement, it is important to consider the effect of crop coefficient (Kc) and the effect of climate on crop water requirement, which is the reference crop evapotranspiration (ETo) [10] as indicated in Table 3. Crop water requirement can be calculated as:

$$ETc = [ETo * Kc]$$

Where:

ETc-Crop evapotranspiration,
ETo-Reference evapotranspiration,
Kc-Crop Coefficient

2.5. Irrigation Water Application

This is defined as the total amount of water needed to grow and produce a given crop with irrigation in a given location [8]. Irrigation water was applied to the field by using the following equations:

$$Bd = \left[\frac{Md}{V} \right]$$

Where:

Md-Dry mass of the soil,
V-Volume of core sampler

$$TAW = [FC-PWP] * Rz * Bd$$

Where:

TAW-Total Available Water,
FC-Field Capacity,
PWP-Permanent Wilting Point,
Rz-Root zone

$$RAW = [TAW * P]$$

Where:

RAW-Readily Available Water,
P (%)-Allowable Soil Depletions

$$I = \left[\frac{NI}{ETc} \right]$$

Where:

I-Irrigation interval,
NI-Net Irrigation

$$t = \left[\frac{A * GI}{6Q} \right]$$

Where:

t-time of application (min),
A- Area plot (m²),
GI-Gross Irrigation (cm),
Q-Flow discharge (l/sec)

$$Ea = \left[\frac{NI}{GI} \right]$$

Where:

Ea-Application Efficiency

Table 3. Mean monthly ETo of the study area

Months	ETo mm/day
December	3.74
January	3.87
February	4.14
March	4.32
April	3.91
May	3.43
June	3.15
July	2.61
August	2.78
September	3.19
October	3.67
November	3.91
Average	3.56

2.6. Water productivity

Water productivity plays a crucial role in modern agriculture to increase yield production both under rain fed and irrigated conditions. Water productivity with dimensions of kg/m³ is defined as the ratio of the mass of marketable yield (Y) to the volume of water consumed by the crop (Wa). Mathematically, water productivity can be represented as follows in equation [11].

$$WP = \left[\frac{Y}{Wa} \right]$$

Where

WP-Water Productivity (Kg/m³),

Y-Economic Yield (kg),

Wa-Total Water applied (m³)

2.7. Partial budget analysis

It was carried out to compare the effects of water applied, input cost, and return to the producers among different treatments. Economic analysis was employed as suggested by [12]. To determine water application levels based on cost and benefits and recommend feasible treatments.

2.8. Data collection and analysis

Data collected from the field for the analysis were irrigation water applied for water productivity, number of pods per plant, plant height, pod length, pod weight and total fresh yield. Analysis was carried out to compare the treatment effect on yield and water productivity of hot pepper. All relevant variables were subject to analysis of variance (ANOVA) that is appropriate for Randomized Complete Block Design (RCBD) [13]. The combined analysis of variance across years was conducted by using the analysis for Statistix software version 10 to determine the differences among treatment effects.

3. Results and discussion

3.1 Effects of irrigation scheduling on hot pepper yield

The maximum yield (96.67Qt/ha) was obtained from 100%MAD technology and minimum (88Qt/ha) was acquired from farmer practices with 9.85% yield advantages as shown in Table 4. The pod yield acquired from the study was higher than the previous study of Malka-Shote variety (30.95Qt/ha) [14] and the local variety (53.66Qt/ha) [15]. The yield obtained from the study was higher than other the same studies of (13.05Qt/ha) [16]. The result as compared to other studies indicates that the environment is more favorable for hot pepper production under irrigation scheduling.

Application irrigation scheduling intervals was at five days in the initial stage and seven day intervals in the rest of development, mid and late stages of the growing period were appropriate for hot pepper production. The higher water productivity (2.21 kg/m³) for fresh hot pepper was recorded using

100%MAD at 30% of depletion factor, which is the appropriate value for utilization efficiency for fresh hot pepper containing about 90% moisture varies between 1.5 and 3.0 kg/m³ [17]. Physical performance photo of hot pepper at the field and data collection was indicated in Figs. 2 and 3.



Figure 2. Field performance of hot pepper during stand and yield data collection



Figure 3. Collected pods of hot pepper and measuring yield data collection.

Irrigation day interval affects water productivity and yield of hot pepper. Irrigation scheduling technology saves total seasonal irrigating days and depth of water as shown in Table 5. There was nine days irrigation round difference occurred between scheduling technology and farmers practices. As the study indicates, irrigation scheduling technology saves water depth applied as compared to farmers' practices. Water saved through reducing the irrigation duty can be used for irrigation when needed for extra production. It is recognized that appropriate irrigation scheduling should lead to improvements in irrigation management performance, especially at farm level. As a Table 6 revealed that 106.9mm water was saved through irrigation scheduling technology with an advantage 19.7% over farmers' practices.

Table 4. Intermediate Result of one year data

Trts	NPPP	PH (cm)	PL (cm)	PW (gm)	TY (Qt/ha)	WP (kg/ha)
100%MAD	81.07	62.33	9.87	316.67a	96.67	2.21a
Farmer Practices	61.60	57.33	9.03	231.67b	88.00	1.62b
Grand Mean	71.33	59.83	9.45	274.20	92.33	1.92
CV	15.41	7.38	2.16	3.41	4.92	8.35
LSD (5%)	NS	NS	NS	32.86	NS	0.56

Trts-Treatments, NPPP- Number of Pods per Plant, PH- Plant Height, PL-Pod Length, PW-Pod Weight, TY- Total Yield, WP-Water Productivity.

Table 5. Irrigation water depth and frequencies

Growing period	Irrigation intervals	Irrigation rounds(days)		Irrigation Water Depth(mm)	
		100%MAD	FP	100%MAD	FP
Initial	Five days	5	7	114.97	135.95
Development	Seven days	5	8	114.97	155.37
Mid stage	Seven days	5	6	114.97	116.53
Late stages	Seven days	4	7	91.98	135.95
Total		19	28	436.9	543.8

Table 6. Advantages of water saved through irrigation scheduling over farmer practices

Treatments	Total water(mm)	Water saved (mm)	Advantages (%)
100%MAD	436.9	106.9	19.7
Farmer Practice	543.8	-	-

Table 7. Benefit cost ratio analysis on (ha) bases

Variable	Cost (ETB) Items	100%MAD	Farmers Practice
	Seed	15,600	15,600
	Land preparation	4800	4300
	Fertilizer	5700	5700
	Pesticide chemicals	5000	7000
	Watering	7800	14400
	Harvesting	3600	3900
	Transporting to market	5000	5000
Total Cost (ETB)		47,500	55,900
Yield(kg/ha)		9667	8800
10% Adjusted yield(kg/ha)		8700.7	7920
Gross revenue (ETB/ha)		522,018	475,200
Net Benefit (ETB/ha)		474,518	419,300
Benefit Cost Ratio		9.98	7.50

Partial budget analysis as shown in Table 7 indicates that, 474,518ETB/ha and 419,300ETB/ha on the seasonal market acquired from 100%MAD and Farmers practice respectively.

The income acquired was very interesting economic advantage for famers to improve their livelihood. The benefit cost ratio (B: C) of the two treatments were (9.98) from 100%MAD and (7.5) from the farmers' practices, which indicates profitability or cash flow

from the project. Therefore, the project is expected to deliver a positive net present value to a firm and its investors with (B: C) greater than one.

Randomly farmers preferred irrigation scheduling technology by considering different criteria's of comparison and the technology ranked first as shown in Table 8. The criteria's considered were labor saving, water saving, pod increment, crop adaptation for the technology and ease for handlings.

Table 8. Farmers' perception on irrigation scheduling technology

Treatments	Labor saving	Water saving	Yield increment	Adaptation of crop through irrigation	Technology easiness for handling	Grand Total	Ranking
100%MAD	21	18	15	16	12	82	1
FP	7	10	13	12	16	58	2

Criteria used on irrigation technology selection and participants feedback (N=28)

4. Conclusions

Irrigation amount and time of application enable the farmer to schedule water rotation among the various fields to minimize crop water stress and maximize yields. Hot pepper is an economically and traditionally feasible an important crop mainly for small-scale farmers as a daily food. Local farmers economically benefited from the irrigated pepper production through irrigation scheduling technology. Irrigation scheduling saves vitally time, water, labor and increases farm gate income with higher pod yield and water productivity. Scheduling technology is also an important technology for different planning strategies under irrigated crop production and managing water sustainably. Improving water productivity has vital advantages in small-scale irrigated hot pepper production that ensures food security and livelihood. Therefore, irrigation scheduling should be recommended for increasing both fresh pod yield and water productivity in the areas.

Authors' contributions

Proposal development, field work, data analysis, data interpretation, draft preparation, final manuscript written, edited and resubmitted, M.H.; Field follow up and data collections, D.M.

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Availability of data and materials

All necessary data will be made available on request according to the journal policy.

Conflicts of interest

No potential conflict of interest was reported from the author(s).

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