

Research Article

Determination of Irrigation Interval and Optimum Water Demand of Wheat at Eastern Hararghe zone of Oromia

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Abstract

Soil moisture based application of irrigation water is crucial for obtaining optimum irrigation scheduling of crop. The objectives of this study were determining optimum irrigation interval, irrigation frequency and optimum water demand of wheat for better production. The result indicates that maximum irrigation frequency and maximum irrigation water was applied by 60% ASMDL. Minimum irrigation frequency and minimum water was applied by 140% ASMDL treatment. A narrow irrigation interval was applied by 60% ASMDL and elongated irrigation interval was applied by 140% ASMDL. The result show that, maximum plant height, number of productive tillers, straw yield and grain yield was obtained by 60% ASMDL treatment. The result indicates that, statistically there is no significance difference between 80% ASMDL and 60% ASMDL treatments in terms of wheat grain yield. The result implies that, as irrigation water is applied more frequently and in short interval the wheat produce more tiller which leads to maximum grain yield. Maximum water productivity (2.078 kg/m³) was obtained by scheduling irrigation at 100% ASMDL. Statistically there is no significance difference between 80% ASMDL and 100% ASMDL in terms of water productivity. Minimum water productivity was obtained by scheduling irrigation at 140% ASMDL. The result show that, optimum grain yield (41.69 qt/ha) and optimum water productivity (2.001 kg/m³) was obtained by scheduling irrigation at 80% ASMDL treatment than others. The lowest grain wheat yield (26.44 qt/ha) and lowest water productivity (1.716 kg/ha) was obtained by scheduling irrigation at 140% ASMDL treatment. Therefore, scheduling irrigation at 80% ASMDL (at $p=0.4$) has been recommended for wheat with 5 day, 7 day, 5 day and 12 day irrigation interval at initial, development, mid and maturity stage of wheat respectively in the study area and same agro-ecology.

Keywords

Irrigation Interval, Optimum Water Demand, Wheat

1. Introduction

Soil moisture monitoring before and after irrigation plays an important role in optimizing irrigation practices, conserving water, improving profit of crop, and preserving soil [10]. It enables farmers to optimize irrigation timing and water application, resulting in efficient resource use and improved agricultural results. Soil moisture-based irrigation

scheduling is a method that uses real-time soil moisture data to determine when and how much to irrigate [10]. Wheat (*Triticum aestivum* L.) is one of the leading cereals in the world and it is the world's most widely cultivated crop which ranks first followed by rice [3]. The production of irrigated wheat was started largely in our country Ethiopia to over-

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come food security problem. The main reasons for low productivity of wheat are improper scheduling of irrigation and poor crop establishment method [11]. About 30% of wheat production is lost due to lack of appropriate irrigation water and 40% yield loss due to lack of nutrient contents in soil [15].

Irrigation frequency has a significant influence on growth and yield of wheat. Besides rainfall, land type and soil texture are two important factors that determine the status of soil moisture. In light textured soil with high infiltration rate, wheat crop is more vulnerable to moisture stress. Mid-term drought around the heading period is more common. Recently, numerous studies dealing with crop production and water use efficiency under irrigation showed that proper irrigation intervals can increase crop yield, by improving soil water condition and their water use efficiency [14].

Timely application of irrigation water can avoid over-and under irrigation, hence guaranteeing more optimal growing conditions throughout the season and increasing water productivity [6]. Irrigation schedules based on local environmental conditions, crop and soil type allow more sustainable use of water resources in agriculture. Such irrigation schedules help the farmer to apply the required amount of water to a particular crop at the appropriate time and ensure sustainable agricultural water management [7].

However, enough irrigation water and nutrient supply can increase yield up to 70% [15]. Irrigation frequency and irrigation interval has a significant influence on the growth and yield of wheat. Proper time of irrigation especially proper irrigation interval is very important for successful growth of wheat and it has a great impact on higher grain yield. Different irrigation interval and frequency can bring significant effect on wheat production [15]. Therefore, the activity was done with the objectives of determining optimum irrigation interval, irrigation frequency and optimum water demand of wheat for better production.

2. Materials and Methods

2.1. Experimental Site Description

The experiment was conducted at Kombolcha District of Estern hararghe zone of Oromia on Kombolcha Polytechnic College located at 09° 25' 50'' of north latitude, and 42°10' 20'' east longitude with elevation of 2160 m a.s.l. It has erratic and uneven in distribution of rainfall, with mean minimum and maximum temperatures of 10 °C and 27.8 °C, respectively. The sources of irrigation water was manually drilling tube well.

2.2. Experimental Design

The experiment was laid out in Randomized Complete Block Design (RCBD) consisting of five treatments with

three replication. The treatment combination were five soil moisture depletion level (SMDL) which determine the irrigation scheduling of wheat based on FAO recommended allowable soil moisture depletion (ASMDL). There were 15 experimental plots and the space between each plot and block were 2 m respectively. Shorima wheat variety was used as crop material.

Table 1. The arrangement of treatment based on different soil moisture depletion level.

Treatment	Treatment Description
SMDL ₁	60% of ASMDL
SMDL ₂	80% of ASMDL
SMDL _{3*}	100% of ASMDL *
SMDL ₄	120% of ASMDL
SMDL ₅	140% of ASMDL

Where; SMDL- soil moisture depletion level, ASMDL- allowable soil moisture depletion level

2.3. Furrow and Ridge Preparation Method

At the beginning of the experiment the land was plowed and leveled using a tractor to make it suitable for laying the experiment and to create a suitable slope for the experiment. After the land was level, furrow preparation was done with furrow maker spaced at 60 cm using a tractor. Then after the land was prepared well, furrow and ridge was made by tractor as recommended dimension. Furrow spacing was 60 cm, wheat row spacing was 20 cm and width of channel of furrow was 40 cm. The wheat was planted on two sides of ridges so that one furrow or which used as irrigation canal was irrigated two rows of wheat. UREA and NPS was the two fertilizers applied equally for each treatment with a rate of 150 kg/ha and 100 kg/ha, respectively. The fertilizer dose per plot was calculated to plot level and applied for each plot. Weeding was done as required as any weed in the field seen.

2.4. Determination of Crop Water Requirement of Wheat

Long term climatic data records such as rainfall, maximum and minimum temperature, wind speed, relative humidity, and sunshine hours was collected from the nearest meteorological station for determination of wheat water requirements. Reference evapotranspiration (ET_o) of wheat was computed using CROPWAT model version 8.0 [12]. The CROPWAT model calculates ET_o based on the formula of FAO Penman-Monteith method. Evapotranspiration of the crop was determined by multiplying the crop coefficient (K_c) of the crop by the reference evapotranspiration (ET_o). Crop

coefficient was collected from FAO Irrigation and Drainage Paper 56 [1] for wheat. Based on the Kc values of the crop and length of each growth stages, crop coefficient was interpolated for development and late season.

2.5. Irrigation Scheduling

The irrigation scheduling was done based on soil water depletion replenishments. The soil water content was monitored using the gravimetric method and digital smart soil moisture meter (*DELTA-HH2 model*), just *before* and *after* full irrigation to maintain the soil water between allowable depletion level and field capacity.

2.6. Determination of Net Irrigation Water Requirement

$$I_n = ET_c - PE \quad (1)$$

Where;

I_n -Net Irrigation Depth (mm), ET_c - The Crop Water Requirement (mm) and Pe -The Effective Rainfall (mm), Effective Rainfall Was Computed Using the Equation, $Pe_{eff} = 0.6 * P - 10$ for precipitation less or equal to 70 mm, $Pe_{eff} = 0.8 * P - 24$ for precipitation greater than 70 mm, Where Pe_{eff} - Effective Precipitation (mm) P - Precipitation (mm).

2.7. Gross Irrigation Depth

Irrigation efficiency was taken as 60%, which is common for surface irrigation method in furrow irrigation [2]. Based on the net irrigation depth and irrigation application efficiency, the gross irrigation water requirement was calculated as:

$$I_g = \frac{I_n}{E_a} \quad (2)$$

Where;

I_g - Gross Irrigation Depth (mm), I_n -Net Irrigation Depth (mm) and E_a -Furrow Application Efficiency (%).

Time required to irrigate each treatment was calculated from the ratio of volume of applied water to the discharge-head relation of 3-inch PF. The time required to deliver the desired depth of water into each furrow was calculated using equation given by [4].

$$T = \frac{I_g * W * L}{6Q} \quad (3)$$

Where; I_g = gross depth of water applied (cm), T = Application Time (min), W = Space of Furrow of the Plot (m), L = Length Furrow of the Plot (m) and Q = Flow Rate (l/s).

2.8. Water Productivity

Water productivity is defined as crop yield per unit volume of water supply to the crops. In this study crop water productivity was estimated as the ratio of onion and potato yield to the total irrigation depth applied during the season. It is expressed as:

$$Wp = \frac{Y}{W} \quad (4)$$

Where, Y is onion and potato yield (kg/ha) and W is irrigation depth applied during the season (m^3/ha).

2.9. Data Analysis

The data were subjected to analysis of variance (ANOVA) using GenStat software. Treatment means were compared using the least significant difference (LSD) at 5% level of probability.

3. Result and Discussion

3.1. Analysis of Soil Property of Experimental Site for CWR Input

Soil physical property used for CropWat input used for determination crop water requirement of wheat was analyzed at Haramaya University soil laboratory. The result of soil physical property analysis shown that the average composition of sand, clay, and silt percentages was 43.5, 31.25, and 25.25, respectively. Thus, according to the USDA soil textural classification, the particle size distribution of the experimental site revealed that the soil textural class is clay loam. Bulk density of experimental site was found between the range of 1.13 g/cm^3 - 1.31 g/cm^3 .

Table 2. Soil physical property of experimental site.

D(cm)	Sand	clay	silt	Textural class	BD (g/cm^3)	FC (%)	PWP (%)	TAW in (mm/m)
0-15	47	27	26	Sandy clay loam	1.31	32.60	18.20	28.29
15-30	43	30	27	Clay loam	1.20	31.20	16.00	27.36
30-45	43	33	24	Clay loam	1.13	34.40	15.20	28.80

D(cm)	Sand	clay	silt	Textural class	BD (g/cm ³)	FC (%)	PWP (%)	TAW in (mm/m)
45-60	41	35	24	Clay loam	1.14	40.30	16.80	40.18
Total available water in effective root zone of mm/m								124.63

3.2. Wheat Irrigation Scheduling Applied Based on SMDL Treatment

Different irrigation scheduling (irrigation interval and irrigation frequency) was determined based on different soil moisture depletion treatments.

Table 3. Wheat irrigation scheduling determined at different growth stage.

Treatments	Depletion fraction (P)	Irrigation frequency	Irrigation interval				Water used (m ³ /ha)
			Initial	Dev	Mid	End	
60% of ASMDL	0.3	20	4	6	5	11	4095.00
80% of ASMDL	0.4	17	5	7	5	12	3471.60
100% of ASMDL*	0.5	15	5	8	6	13	3181.60
120% of ASMDL	0.6	11	7	10	9	14	2950.00
140% of ASMDL	0.7	9	8	13	12	15	2568.00

Where, ASMDL - allowable soil moisture depletion level

The result shown that, maximum irrigation frequency and maximum irrigation water was applied by 60% ASMDL treatment. The result in agreement with the finding of [8] who report that maximum number of irrigation is applied when it irrigated closely. Minimum irrigation frequency and minimum water was applied by 140% ASMDL treatment. A narrow irrigation interval was applied by 60% ASMDL and elongated irrigation interval was applied by 140% ASMDL. Optimum or medium irrigation interval was obtained by scheduling irrigation at 80% ASMDL treatment than the others.

3.3. Effect of Soil Moisture Depletion Level on Wheat Yield and Yield Component

Yield and yield components of wheat was significantly affected by scheduling irrigation at different soil moisture depletion treatments. Yield of wheat was affected as crop is more stressed meaning that when irrigation interval is elongated.

Table 4. Effect of soil moisture depletion level on wheat yield and yield component.

Treatments	Plant height (cm)	No of tiller per plant	Grain Yield (qt/ha)	Straw Yield (qt/ha)
60%ASMDL	69.33 a	5.000 a	44.22 a	48.42 a
80%ASMDL	64.67 b	4.333 b	41.69 ab	45.50 b
100%ASMDL	63.17 c	4.000 b	39.67 b	42.83 c
120%ASMDL	55.77 d	3.167 c	34.11 c	40.42d
140%ASMDL	46.67 e	2.000 d	26.44 d	31.17e
CV	1.9	13.3	6.2	1.5
LSD	1.365	0.5876	2.755	0.735

Note Mean with the same letter is not significantly different

The above ANOVA table show that, maximum plant height, number of productive tillers, straw yield and grain yield was obtained by 60% ASMDL treatment. The finding is in line with the result report as maximum yield is obtained when wheat is closely irrigated [13]. The finding is also in line with the result report as more wheat grain yield is obtained with short interval irrigation [5]. The result implies that, as irrigation water is applied more frequently and in short interval the wheat produce more tiller which leads to maximum grain yield. The result is in agreement with the finding reported as, the highest wheat grain yield (4,959 kg ha⁻¹) was obtained scheduling irrigation at 60% of ASMDL [9].

The result indicates that, statistically there is no significance difference between 80% ASMDL and 100% ASMDL treatments in terms of grain yield. Minimum plant height,

number of productive tillers, straw yield and grain yield was obtained by 140% ASMDL treatment. The result shown that, both plant height and straw yield were decreased as irrigation frequency decreased and vice versa.

Effect of soil moisture depletion level on water productivity

Irrigation water productivity was also significantly affected by scheduling irrigation at different soil moisture depletion treatments.

Maximum water productivity (2.078 kg/m³) was obtained at scheduling irrigation at 100 % ASMDL. Statistically there is no significance difference between 80% ASMDL and 100% ASMDL in terms of water productivity. Minimum water productivity was obtained by scheduling irrigation at 140% ASMDL.

Table 5. Effect of soil moisture depletion level on water productivity.

Treatments	Grain Yield (qt/ha)	WP (kg/m ³)
60% of ASMD	44.22 a	1.800 cd
80% of ASMD	41.69 ab	2.001 ab
100% of ASMD	39.67 b	2.078 a
120% of ASMD	34.11 c	1.914b c
140% of ASMD	26.44 d	1.716 d
CV	6.2	6.2
LSD	2.755	0.140

3.4. Effect of Irrigation Scheduling on Ky and Yield Reduction of Wheat

The yield response to different irrigation scheduling is also affected as the wheat is more stressed and irrigation interval far apart from each other's.

The result show that, yield response factor (Ky) was greater than one at both 120% ASMDL and 140% ASMDL treatments. When ky is greater than one, it mean that, there is significance reduction on yield due to treatments. The yield reduction in terms of percentage was also high at those treatments, which implies that, the irrigation scheduling bring significant yield reduction on yield.

Table 6. Effect of irrigation scheduling on Ky and yield reduction of Wheat.

Treatments	Yield (qt/ha)	Yield reduction (%)	Yield response factor Ky
60% ASMDL	44.22 a	-	-
80% ASMDL	41.69 ab	-	-
100% ASMDL*	39.67 b	*	*
120% ASMDL	34.11 c	14.01	1.923
140% ASMDL	26.44 d	33.35	1.730

4. Conclusion and Recommendation

The result on effect of different irrigation schedule on Wheat yield indicate that, there was significance difference between treatments. The result show that, optimum grain yield (41.69 qt/ha) and optimum water productivity (2.001 kg/m³) was obtained by scheduling irrigation at 80% ASMDL treatment than others. The lowest grain wheat yield (26.44 qt/ha) and lowest water productivity (1.716 kg/ha) was obtained by scheduling irrigation at 140% ASMDL treatment. Therefore, scheduling irrigation at 80% ASMDL (at p=0.4) has been recommended for wheat with 5 day, 7 day, 5 day and 12 day irrigation interval at initial, development, mid and maturity stage of wheat respectively in the study area and same agro-ecology.

Abbreviations

ASMDL	Allowable Soil Moisture Depletion Level
WP	Water Productivity
BD	Bulk Density
ETo	Reference Evapotranspiration
FAO	Food and Agricultural Organization
FC	Field Capacity
ha	Hectare
kg	Kilogram
PWP	Permanent Wilting Point
qt	Quintal
TAW	Total Available Water
ANOVA	Analysis of Variance

Conflicts of Interest

The authors declare no conflicts of interest.

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