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Research Article

Determination of Optimal Irrigation Scheduling for Potato Crop Under Furrow Irrigation Method in Eastern Hararghe Zone of Oromia

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Abstract

Applying water using appropriate irrigation scheduling is crucial for enhancing of irrigation water use efficiency. This activity was done with the objectives of developing optimum irrigation regimes (when and how much to irrigate) for potato crop and evaluate the effect different irrigation scheduling on water productivity and yield of potato crop. The results indicate that, maximum irrigation frequency was obtained by scheduling irrigation at 60% ASMDL treatment. Minimum irrigation frequency was obtained by 140% ASMDL treatment. The result indicates that, maximum yield (335.7 qt/ha) was obtained by scheduling irrigation at 80% ASMDL treatment. The next maximum potato yield was obtained by scheduling irrigation at 100% ASMDL. Minimum potato yield (208.1 qt/ha) was obtained by scheduling irrigation at 140%ASMD treatment. 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 potato yield due to treatments. The result on irrigation scheduling of potato indicate that, maximum water productivity (12.34 kg/m^3) and optimum yield (321.4 qt/ha) was obtained by scheduling irrigation at 100% ASMDL treatment than others. So, based on obtained water productivity and optimum yield, scheduling irrigation at 100% ASMDL is recommended for Potato with 8 day, 9 day, 10 day 13 day irrigation interval at initial, development, mid and maturity stage of Potato respectively.

Keywords

Irrigation Scheduling, Optimum Water Demand, Potato

1. Introduction

Agriculture is one of the main consumers of freshwater resources in the world. It is consuming more than two two-thirds of total withdrawals [2]. Agriculture dominates global water consumption, accounting for 70% of total with drawals [9]. In many parts of the world, irrigation water has been over-exploited and over-used and the freshwater shortage is becoming critical in the arid and semiarid areas of the world. The rapid increase of the world population and the corresponding demand for extra water by sectors such as industries and municipals forces the agricultural sector to use its irrigation water more efficiently on the one hand and to produce more food on the other hand [7].

As the world, the area equipped for irrigation is projected to increase by about six percent by 2050 [8]. Water withdrawals

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for irrigation are projected to increase by about 10 percent by 2050. Irrigated food production is projected to increase by 38 percent, due to projected increases in cropping intensities and increases in productivity. Overall, the scope to improve both land and water productivity on irrigation schemes is considerable, as illustrated by the large discrepancies observed between schemes and within schemes. The efficiency of water use in irrigated agriculture is a global priority to address water scarcity [10].

Growing demands for water in cities and industries put further pressure on agricultural water supplies. Wasteful irrigation practices exacerbate the issue, depleting regional water resources even faster [11]. Although Ethiopia's water resource is large, very little of it has been developed for agriculture and other purposes. Climate change has altered hydrological cycles and weather patterns, resulting into an increase of intensity and frequencies of extreme weather conditions, with significant impacts on the agricultural sector [5]. Irrigation is the most effective method to increase potato yield [13]. However, unreasonable irrigation in potato production leads to serious water resource waste and threatens the sustainable use of water resources [14]. Modern strategies such as drip irrigation, deficit irrigation, and partial root-zone drying have been implemented to optimize water use efficiency [15].

The potato is the fourth largest food crop in the world after maize, rice and wheat, in the order of extent of the area planted [12]. Potato (*Solanum tuberosum L.*) is one of the most important vegetable crops grown in the high and mid altitude areas of Ethiopia. It serves as food and cash crop for small scale farmers, occupies the largest area compared to other vegetable crops and produces more food per unit area and time compared to cereal crops [3]. Potato is major vegetable crop produced under irrigation in study area-kombolcha district of eastern hararghe zone so, it's important to determine their appropriate irrigation scheduling. So the activity was done with the objectives of developing optimum irrigation regimes (when and how much to irrigate) for potato crop and evaluate the effect different irrigation scheduling on water productivity and yield of potato crop.

2. Material and Methods

2.1. Experimental Site Description

The experiment was conducted at Kombolcha District of Estern hararghe zone of Oromia on Kombolcha poly-technic 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℃ and 27.8℃, respectively. The source 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 replications. The treatment combinations were five soil moisture depletion level (SMDL) which determine the irrigation scheduling of potato. There were 15 experimental plots and the space between each plot and block were 2 m respectively. Gudane potato variety was used as crop material.

Table 1. *Arrangement of treatments.*

Treatment	Treatment Description
T1	60% of ASMDL
T2	80% of ASMDL
T3	100% of ASMDL*
T4	120% of ASMDL
T5	140% of ASMDL

Where; ASMDL- allowable soil moisture depletion level

2.3. Determination of Crop Water Requirement of Potato

Climatic data (rainfall, temperature, and wind speed, relative humidity and sun shine hours) were used for determination of Water Requirement of potato. The CROPWAT model version 8.0 calculates ETo based on the formula of FAO Penman-Monteith method.

2.4. 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.

2.5. Determination of Net Irrigation Water Requirement

$$\text{IN} = ETc - PE \quad (1)$$

Where;

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

2.6. Gross Irrigation Depth

Irrigation efficiency was taken as 60%, which is common for surface irrigation method in furrow irrigation [1]. Based on the net irrigation depth and irrigation application efficiency, the gross irrigation water requirement was calculated as:

$$Ig = \frac{\text{In}}{\text{Ea}} \quad (2)$$

Where;

I_g = Gross Irrigation Depth (mm), I_n = Net Irrigation Depth (mm) and Ea = 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 [6].

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

Where; Ig = 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).

2.7. 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 potato yield to the total irrigation depth applied during the season. It is expressed as:

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

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

2.8. 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 potato was analyzed at Haramaya University soil laboratory.

Table 2. *Soil physical property of experimental site.*

D (cm)	Sand	clay	silt	Textural class	BD (g/cm^3)	FC (%)	PWP (%)	TAW (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
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

The result of soil physical property analysis showed that the average composition of clay, silt and sand percentages were 32, 25, and 43, 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. The bulk density of study area was acceptable for crop growth for movement of air and water through the soil according to [4].

3.2. Potato Irrigation Scheduling Applied Based on ASMDL Treatment

Different irrigation scheduling (irrigation interval and irrigation frequency) was determined based on different soil moisture depletion treatments for potato. They are varying among the growing stage of potato according treatment.

Table 3. *Irrigation scheduling applied based on ASMD treatment.*

Treatments	Depletion fraction (P)	Irrigation frequency	Irrigation interval				Water used (m^3/ha)
			Initial	Dev.	Mid	End	
60% ASMDL	0.21	17	5	7	9	10	4940.00
80% ASMDL	0.28	15	7	8	10	12	4721.70
100% ASMDL*	0.35*	13	8	9	10	13	4341.00
120% ASMDL	0.42	12	9	10	12	14	4160.00
140% ASMDL	0.49	9	10	12	13	16	3900.00

From the above table maximum irrigation frequency was obtained by 60% ASMDL treatment. Minimum irrigation frequency was obtained by 140% ASMDL treatment. The irrigation interval had directly related with the percentage of allowable soil moisture depletion level (Table 3) above.

3.3. Effect of Different Irrigation Schedule on Potato Yield and Yield Components

Both yield and yield components of potato were significantly affected by different irrigation scheduling treatments at different soil moisture depletion level treatments.

Table 4. *Effect of different irrigation schedule on potato yield and yield components.*

Treatments	Plant Height (cm)	Number of tuber/plant	Tuber yield (qt/ha)
60% ASMDL	54.52a	13.50ab	299.0c
80% ASMDL	52.88b	14.46a	335.7a
100% ASMDL	47.83c	12.50b	321.4b
120% ASMDL	42.94d	9.22c	273.1d
140% ASMDL	39.10e	4.83d	208.1e
CV	1.6	7.9	2.3
LSD	0.886	1.030	7.883

The ANOVA table shows that, there is significance difference between treatments in terms yield components, total yield and water productivity. The result indicates that, maximum yield was obtained by scheduling irrigation at 80% ASMDL treatment followed by scheduling irrigation at 100% ASMDL. Minimum potato yield was obtained by scheduling irrigation at 140% ASMDL treatment. In terms of plant height, there was significance difference between potato plant heights, accordingly, maximum potato height was obtained by 60% ASMDL treatment and minimum plant height was obtained by scheduling irrigation at 140% ASMDL treatment. Maximum number of potato tuber per plant was obtained by scheduling irrigation at 80% ASMDL treatment. But, statistically, there is no significance difference between 60% ASMDL and 80% ASMDL treatments in terms of number of potato tuber per plant.

3.4. Effect of Different Irrigation Schedule on Potato Water Productivity

Water productivity of potato was also significantly affected by irrigation scheduling treatments based different soil moisture depletion level.

Table 5. *Effect of different irrigation schedule on potato water productivity.*

Treatments	Tuber yield (qt/ha)	Water productivity (kg/m^3)
60% ASMDL	299.0 c	10.09 d
80% ASMDL	335.7 a	11.85 b
100% ASMDL	321.4 b	12.34 a
120% ASMDL	273.1 d	10.92 c
140% ASMDL	208.1 e	8.89 e
CV	2.3	2.4
LSD	7.883	0.308

The results indicate that, maximum water productivity was obtained by scheduling irrigation at 100% ASMD treatment, which is followed by scheduling irrigation at 80% ASMD treatment. Minimum water productivity was obtained by scheduling irrigation at 140% ASMD treatment.

3.5. Effect of Irrigation Scheduling on Ky and Yield Reduction of Potato

Yield of potato was widely affected as crop is more stressed and large irrigation interval. The yield response factor also comes greater than one at those treatments.

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

Treatments	Yield	Yield reduction (%)	Yield response factor Ky
60% ASMDL	299.0 c	-	-
80% ASMDL	335.7 a	-	-
100% ASMDL*	321.4 b	*	*
120% ASMDL	273.1 d	15.03	1.35
140% ASMDL	208.1 e	35.25	1.27

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 potato yield due to treatments. The yield reduction in terms of percentage was also high at 120% ASMDL and 140% ASMDL treatments, which implies that, the irrigation scheduling bring significant yield reduction on yield at those treatments. The result indicates that, yield reduction was not observed at 60% ASMDL and 80% ASMDL treatments and ky was less than one at those treatments.

4. Conclusion and Recommendation

The result indicates that, maximum yield was obtained by scheduling irrigation at 80% ASMDL treatment followed by scheduling irrigation at 100% ASMDL treatment. Minimum potato yield was obtained by scheduling irrigation at 140% ASMDL treatment. In terms of plant height, there was significance difference between potato plant heights, accordingly, maximum potato height was obtained by 60% ASMDL treatment and minimum plant height was obtained by scheduling irrigation at 140% ASMDL treatment. Even though maximum yield was obtained by scheduling irrigation at 80% ASMDL treatment, maximum water productivity was obtained by scheduling irrigation at 100% ASMDL treatment. So based on obtained result, especially, water productivity, scheduling irrigation at 100% ASMDL is recommended for Potato production with 8 day, 9 day, 10 day and 13 day irrigation interval at initial, development, mid and maturity stage of Potato respectively.

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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