Effect of variable irrigation regime on yield and water productivity of potato at Koga irrigation scheme

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Abstract

In Ethiopia, Irrigation water management is challenged by improper water application. Field experiment was therefore conducted to investigate the effect of irrigation regime on yield and water productivity of potato at Koga irrigation scheme during 2010 and 2012 irrigation seasons. The treatments contained a factorial combination of two irrigation intervals (7 and 10 days) with five irrigation depths (50, 75, 100, 125 and 150% of the crop water requirement) and laid down in a randomized complete block design with three replications. Stand count, marketable tuber yield, total tuber yield and tuber number were collected and analyzed using SAS 9.0 and significant treatment mean differences were separated using least significant difference at 5%. The results depicted that irrigation frequency had significant effect on tuber yield than irrigation depth. The interaction effect of irrigation frequency and depth was significant on total tuber yield and water productivity. Application of 100 %CWR irrigation depth at 7 days irrigation interval gave 10.84 t ha^{-1} marketable yield, 13.2 t ha^{-1} total tuber yield and 1.5-1.8 kg m^{-3} water productivity. Irrigation water requirement of potato was 540.5 mm that corresponds to 17 irrigations throughout the growing season. Therefore, in order to attain an optimum yield and water productivity, at Koga and similar agro ecology areas potato should be irrigated with 100%CWR at 7 days interval.

Key words: Irrigation regime, Koga, marketable yield, potato, tuber yield,

Introduction

Potato is one of the staples crop grown in Ethiopia. The highest production is in the northwest, central, south and southeast parts of the country with sufficient moisture, favourable day to night temperature regimes, and irrigated production potentials. In 2015/16, more than 5 million smallholders were engaged in potato production resulted in a 172% increase compared to 2001/02. Over 3.66 million MT of potato was produced in 2015/16, a 540% increase compared to 2001/02 (CSA, 2002; CSA, 2016). Total area allocated to potato also expanded by over 9% from 0.16 million hectares in 2001/02 to about 0.30 million hectare in 2015/6 (CSA, 2016); an 87.5% increase. Similarly, the average potato yield showed a 122.3% increase from 5.7 t ha^{-1} in 2001/02 to 12.67 t ha^{-1} in 2015/16. The adoption and coverage of 25.2% of the total potato area in the country with improved varieties might have partly contributed to the witnessed productivity gain (Labarta et al., 2012).

The actual potato yield in Ethiopia ranges between 8 and 12 t ha^{-1}; slightly below the average of Africa (10 t ha^{-1}). In 2009/10, Ethiopia achieved yield between 11-12 t ha^{-1}. Nevertheless the yields are below that of Sudan (17 t ha^{-1}) and Egypt (26 t ha^{-1}), (Anton et al., 2012). Several factors are responsible for this discrepancy, among which irrigation water management is the most limiting (Fekadu and Dandena, 2006). Many investigations have been carried out worldwide regarding the effects of irrigation regime on yield of potato (Menelik et al., 2013). However, most of these studies assessed the effect of reduced water stress (irrespective o appropriate irrigation scheduling to the entire growth stage off potato)

Potato irrigation management is to minimize soil water fluctuations and maintain available soil water within the optimum range of 65-85 percent. Irrigation systems best suited to this task are those that are capable of light, uniform, and frequent water applications. An effective irrigation management program must include regular quantitative monitoring of soil water availability, and scheduling irrigations according to crop water use, soil water holding capacity and crop rooting depth. Potato is more sensitive to water stress than most other crops, have relatively shallow root systems, and are commonly grown on coarse-textured soils. These conditions dictate utilization of a quantitative potato irrigation management program for consistent and optimum economic return. Potato is the popular vegetable grown under irrigation in most of the traditional and the recent modern irrigation schemes in Amhara Region. However, the largest production of potato is not supported with improved water management practices to improve its productivity. There is lack of location specific research results of how much water and when to irrigate potato. Hence, the objectives of this study were to determine the crop water requirement and irrigation schedule on the yield of potato and water productivity using CROPWAT computer model and with field experiments at Koga irrigation scheme.

Materials and methods

Site description

The research was conducted during 2011 and 2012 cropping season at Koga irrigation schemes, west Amhara, Ethiopia. Koga irrigation scheme is located in Mecha district; 41 kilometres from Bahir Dar on the way to Addis Ababa via Debremarkos (37°7'29.721" Easting and 11°20'57.859" Northing and at an altitude of 1953 m a.s.l.). The average annual rainfall of the area is about 1118 mm. The mean maximum and minimum temperatures are 26.8 °C and 9.7 °C respectively. The soil type is generally light clay Nitisols. The soil has low available phosphorous (6.12 ppm), medium nitrogen (0.21%) and strongly acidic soil reaction (pH = 4.6). The field capacity (FC) and permanent wilting point of the study area were 32 (%w/w) and 18 (%w/w); respectively.

Methods

CROPWAT 8.0 for Windows was used to estimate daily reference crop evapotranspiration and generate the crop water requirement and the irrigation schedule for potato (Table 1 and 2). Calculations of the crop water requirements and irrigation schedule were carried out taking climate, soil and crop data inputs. In order to estimate the climatic data (wind speed, sunshine hours, relative humidity, minimum and maximum temperature), LOCCLIM, local climate estimator software (FAO, 1992) was used. The estimator uses real mean values from the nearest neighbouring meteorology stations and it interpolated and generated climatic data values for the study site. Based on the technology we used, we assumed 70% application efficiency, and then the gross water requirement was calculated. The demand for water during the growing season varies from one growth stage to another. Values of potential evapotranspiration (ET_O) estimated were adjusted for actual crop ET. Table 3 and 4 show CROPWAT 8 Windows tables for ET. Principally, CropWat outputs generated by default were used to identify irrigation timing when 100% of readily available moisture occurs and application depth where 100% of readily available moisture status is attained. To verify the CropWat output, field experiments were carried out for two consecutive years.

Table 1 Climate and ETo data of Koga

Month	Min Temp °C	Max Temp °C	Humidity %	Wind Km day^{-1}	Sun hours	Rad MJm^{-2}day^{-1}	ETo Mmday^{-1}
January	7.5	26.5	51	1	9.8	21.3	3.13
February	9.2	28	45	1	9.8	22.8	3.48
March	12	29.5	42	1	9.1	23.1	3.8
April	13.3	29.8	43	1	8.8	23.1	3.98
May	14.4	28.9	53	1	8.6	22.4	4.03
June	14	26.6	67	1	6.7	19.2	3.59
July	13.7	24	76	1	4.4	15.9	3.01
August	13.6	24	77	1	4.3	15.9	3
September	12.9	25.1	72	1	5.9	18.2	3.3
October	12.5	26.2	63	1	9	21.9	3.7
November	10.4	26.3	57	1	9.5	21.2	3.35
December	7.9	26.2	54	1	10	21	3.11
Average	11.8	26.8	58	1	8	20.5	3.46

Table 2 Crop water requirements of potato at Koga

Month	Decade	Stage	Kc Coeff.	ETc Mmday^{-1}	ETc Mm dec^{-1}	Eff rain Mm dec^{-1}	Irr. Req. Mm dec^{-1}
Dec	2	Initial	0.4	1.24	3.7	0	3.7
Dec	3	Initial	0.4	1.25	13.7	0	13.7
Jan	1	Development	0.42	1.33	13.3	0	13.2
Jan	2	Development	0.63	1.98	19.8	0	19.8
Jan	3	Development	0.89	2.89	31.8	0	31.8
Feb	1	Mid	1.11	3.73	37.3	0	37.3
Feb	2	Mid	1.13	3.95	39.5	0	39.5
Feb	3	Mid	1.13	4.07	32.5	0.1	32.4
Mar	1	Mid	1.13	4.19	41.9	2	39.9
Mar	2	Late	1.11	4.22	42.2	3	39.2
Mar	3	Late	0.78	3.01	33.2	4.8	28.4
Apr	1	Late	0.45	1.76	10.5	4	7.2
					319.4	14	306.1

Treatment setup

On-farm experiment was conducted in the dry season (December to April) with ten different treatments. Two irrigation intervals (7 and 10 days) and five irrigation levels (50, 75,100,125 and 150% CWR depths) at four growth stages were selected based on CROPWAT 8.0. Thus the following treatments were set and evaluated for verification of the CropWat prediction with field experimentation:

1. 50%CWR at 7 day interval
2. 75%CWR at 7 day interval
3. 100%CWR at 7 day interval
4. 125%CWR at 7 day interval
5. 150%CWR at 7 day interval
6. 50%CWR at 10 day interval
7. 75%CWR at 10 day interval
8. 100%CWR at 10 day interval
9. 125%CWR at 10 day interval
10. 150%CWR at 10 day interval

The treatments were arranged in factorial experiment with randomized complete block design (RCBD) with three replications. The plot size was 3 m by 6 m. Spacing between treatments and block were 1m and 1.5m respectively. The space between plants was 0.3 m and 0.75m between rows was used. Jalenie was the variety used. Di-ammonium phosphate (DAP) fertilizer was applied at a rate of 150 kg ha^{-1} at planting while 117 kg urea ha^{-1} was applied half at planting and the remaining half 45 days after planting. Total tuber yield, marketable yield and unmarketable yield were collected. Water productivity was calculated as the ratio of marketable yield to amount of water consumed based on Arega (2003).

Data Analysis

Collected agronomic data were analyzed using SAS 9.0 statistical software and means were separated using least significant difference at 5% significance level.

Results and discussion

The finding of the research showed that there was significant effect of frequency on tuber yield, marketable yield, number while for other parameters there was significant difference $p<0.05$ between treatments (Table 5 and 6).

Tuber number

Irrigation frequency showed a highly significant effect on total tuber number of potato ($p<0.05$), while it was insignificant for irrigation levels and for the interaction. This result suggests that total tuber number can be controlled more effectively by irrigation frequency than irrigation depth. The total tuber number was significantly reduced from 141 to 106 when the irrigation frequency increased from 10 to 7 days irrigation interval.

Marketable tuber Yield

Irrigation frequency showed a highly significant ($P < 0.001$) effect on marketable tuber yield of potato. The lowest (4.62 t ha^{-1}) and the highest (10.84 t ha^{-1}) marketable tuber yield of potato were obtained for 10 and 7 days irrigation interval, respectively. The effect of irrigation depth on the marketable tuber yield was not significant (Table 5 and 6). The lowest marketable yield (6.58 t ha^{-1}) was recorded from 75% CWR, and reaching maximum (8.74 t ha^{-1}) from 150% CWR. Marketable yield of potato increased with frequent irrigation than when it was applied after longer days. The result was in line with Niguse et al, (2011) that increasing the level of frequency significantly increases marketable tuber yields. However, tested varieties showed less mean performance than varieties tested elsewhere; may be related to the low pH of the soil. Soil pH is an important factor contributing to the overall potato yield and marketable tuber grades. According to Havlin et al, (1999), the optimum soil pH for potato is 5-5.5 while at Koga it is about 4.63. Marketable yield of potato showed positive response up to 100% CWR irrigation depth. Excess water in the soil decreases the oxygen diffusion rate in the root zone (Wan and Kang, 2006) affecting crop yield negatively.

Unmarketable tuber yield

Irrigation frequency showed a highly significant effect on unmarketable tuber yield of potato ($p< 0.05$), while insignificant for irrigation levels and for interaction. This result suggested that unmarketable tuber yield could be managed more effectively by irrigation frequency than irrigation depth. The unmarketable tuber yield was significantly reduced from 3.04 to 2.3 t ha^{-1} when the irrigation frequency increased from 10 to 7 days irrigation interval; implied improper irrigation depth and frequency substantially reduce yields by increasing the proportion of rough and misshaped tubers. A widely fluctuating soil water contents helps for developing tuber defects (Serhat and Abdurrahim, 2009)

Table 5 ANOVA for marketable, unmarketable, total yield and water productivity at Koga

Sources of variation	Df	Mean square: Marketable yield	Unmarketable	Tuber number	Total Yield	Water Productivity
Year (Y)	1	0.06ns	2.1ns	1560ns	2.97ns	0.01ns
Replication (R)	2	10.1ns	3.4ns	718ns	1.83ns	0.2ns
Frequency (F)	1	579.9 **	6.8*	18375**	460.7**	13.7**
Depth (D)	4	10.1ns	0.07ns	287ns	9.2ns	1**
Y*F*D	13	7.3ns	1.7ns	350ns	6.4ns	0.2ns
R*F	2	3.4ns	1.2ns	345ns	0.81ns	0.05ns
F*D	8	3.4ns	2.3ns	1049ns	9.8ns	0.3ns
Error	28	4.7	0.97	857	5.58	0.13
CV (%)		28.1	36.5	23.69	22.6	27.2

Where: Df= Degree of freedom, ns not significant * significant and ** highly significant

Table 6 Marketable yield, unmarketable yield, total yield and water productivity analysis result

Factors		Stand count	Marketable yield t ha^{-1}	Un marketable yield t ha^{-1}	Total tuber number/plot	Total Yield t ha^{-1}	Water Productivity kg m^{-3})
Frequency	7	38.6	10.84	2.36	141	13.2	1.8
	10	24.8	4.62	3.04	106	7.67	0.85
Depth	50	30.58	8.08	2.73	129.6	10.8	1.68
	75	33.3	6.58	2.83	123.4	9.4	1.29
	100	31.25	8.3	2.64	126.5	10.9	1.56
	125	31.9	6.96	2.64	116.8	9.6	1.03
	150	31.75	8.74	2.67	121.4	11.4	1.06

Total tuber yield

Irrigation frequency highly and significant affected ($p < 0.001$) total tuber yield. The lowest (7.67 t ha^{-1}) total tuber yield was obtained from 10 day interval while the highest (13.2 t ha^{-1}) was from 7 days interval. Irrigation levels were not significant in affecting the total tuber yield $p<0.05$. The lowest total yield (9.4 t ha^{-1}) was recorded from 75% CWR and the maximum (11.4 t ha^{-1}) from 150%CWR. The interaction effect of irrigation frequency and depth were not significantly affecting the total tuber yield. The low result of the yield might be due to the occurrence of bacterial wilt. Moreover, low soil pH and high soil temperature may attribute to reduce yield. According to Havlin et al., (1999), the optimum pH for potato production is about 5-5.5. Total yield of potato showed positive response up to 100%CWR of irrigation depth. Applying the right depth of irrigation and frequency increased the total tuber yield. The result of this research agrees with the findings of Bowen (2003). However, further increase in the irrigation level beyond 100 %WR adversely affects total tuber yield may be due to the fact that much higher irrigation depth aggravates the development of physiological disorders that reduces total tuber yield.

Water productivity

Interaction effect between irrigation frequency and depth showed a non-significantly affect 3 ” 0.05) on the productivity of water. The water productivity decreased with increasing depth of

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reducing irrigation interval while water productivity was reduced with increasing irrigation depth. The average maximum yield (13.2 t ha^{-1}) and high water productivity (1.8 kg m^{-3}) were achieved at 7 days interval. The average maximum water productivity (1.68 kg m^{-3}) was achieved by applying 50% CWR. The net irrigation water requirement was found to be 540.5 mm throughout the growing season. Therefore, based on the findings of this research 100% CWR at 7 days interval is recommended for Koga. However, considering water productivity under water stress condition, 50% CWR at 7 day interval could be an alternative option.

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