Evaluation of deficit irrigation for potato production at Sekota, Wag Himra

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Abstract

The field experiment was conducted on potato during the 2006 and 2007 dry season at one of the experimental sites of Sekota Agricultural Research Center, Woleh. The objectives were to identify the amount of deficit and the periods during which water deficit would have limited effect on potato yield, and the periods with maximum water productivity. The method of irrigation application was furrow irrigation. Eight treatments (independent application of 100%, 75%, 50%, and 25% of the crop water requirement (CWR) at the four growth stages; application of 25% of the CWR either at the 1st or 2nd or 3rd or 4th growth stage and 100% application for the other stages) were evaluated in three replications in a RCBD. Irrigation water requirement was determined using CROPWAT program by using climate, rainfall, crop, and soil data as input data. Results showed that 75% water deficit either at the first or fourth growth stage gave comparable and statistically similar yield with that of 100% full watering. Tuber yield reductions of 64%, 39% and 28% were observed with the application of 25%, 50% and 75% of the CWR at all stages, respectively. About 35% and 29% yield reduction was obtained by applying 75% water deficit either at second or third growth stage, respectively. Taking into consideration both yield advantage and water use efficiency, 75% deficit irrigation application only at the 4th growth stage and full irrigation application at other stages is recommended as it gave high tuber yield and saved 1670 m^3 ha^{-1} of irrigation water.

Key words: Deficit irrigation, CROPWAT, moisture stress, potato, water productivity.

Introduction

One of the irrigation management practices which could result in water saving is deficit irrigation. By maintaining the moisture content of the soil below the optimum level during specific growth stages of crops in the season or throughout the growing season, it is possible to identify the periods during which water deficit would have a limited effect on crop production. In a traditional irrigation using furrow irrigation system, where water is allowed to flow in small channels between crop rows, the water is gradually absorbed into the bottom and sides of the furrow to wet the soil. But the problem here is that the water reaches to the furrows or to the fields without applying appropriate amount and duration of irrigation or without knowing exactly the crop water requirement and required irrigation interval. They simply allow water to flow in to the irrigated fields which often leads to the water being lost in the form of evaporation and deep percolation in all growing stages. Therefore farmers do not get an optimum yield and their water use efficiency is poor.

Potato (*Solanum tuberosum*) is a leading food and vegetable crop in many parts of Ethiopia. It is mainly produced during the rainy season. Since potato can be harvested and consumed during the season when food unavailability is common, it is considered as a food security crop in most of the drought prone areas. Recently, potato production is expanding using small scale irrigation systems. The yield however, has remained stagnant. This low yield is caused, in part, by improper irrigation management. The crop is very sensitive to irrigation. The yield quality and disease resistance are greatly influenced by timing, amount and frequency of irrigation applied. The farmers, on the other hand, apply water to the crop regardless of whether the plant actually needs water at specific growth stage (Kirda *et al*., 1999). From an economics standpoint, maximum profit for farmers may be obtained with the fulfillment of the entire crop water requirements.

In the dry land countries like Morocco, they manage their water by stressing the crop at one of the growth stages; initial stage, vegetative development, yield formation or root growth and ripening. By doing so, they simply select the optimum yield rather than the maximum yield and manage and save the limited water easily. Considering moisture stress situations in our country, particularly in the Sekota dryland areas, where the amount of rainfall is small and erratic and thus there is scarcity of water sources for irrigation production, deficit water management methods should be sought and applied to maximize crop production. The intention of this study was to make inferences on water saving on irrigated areas through adequate irrigation management, and at the same time to evaluate and identify crop growth stages which withstand moisture stress with limited effect on crop yield. Thus, an experiment was conducted with the objective of identifying sensitive crop growth stages to water stress, and to identify the amount of deficit and corresponding growth stages during which potato could withstand water stress with limited effect on its yield.

Materials and methods

The experiment was conducted at Woleh in Sekota Woreda during the 2006 and 2007 irrigation seasons. The experimental site is located at 12^0 $35^{'}$ 24'' N and 39^0 05' 48'' E with an altitude of 2126 m above sea level (a.s.l). The area has total annual rainfall of 830 mm, mean maximum temperature of 25 ^OC, and mean minimum temperature of 8 ^OC. The soil of the experimental site was silt clay soil. Potato was planted with a spacing of 75 cm between ridges and 30 cm between plants. The recommended fertilizer rate of 110 kg N ha^{-1} and 90 kg P_2O_5 ha^{-1} was applied.

Crop water requirement and irrigation requirement was determined using CROPWAT program. The programme uses locally collected input data for crop, soil, and climate. Crop water requirement and irrigation interval was computed using FAO modified Penman-Monteith equation. Measurements of soil moisture content were done at the beginning of each crop stage. Soil samples were taken from the experimental field to determine the physicochemical properties of the soil. Thirty years metrological data for Lalibela and Maichew stations were collected from the National Meteorological Service Agency. Interpolations using LocClim software were performed to compute climate variables for the study location, Sekota.

Four crop growth stages were subjected to water deficit at different stress levels. Accordingly, the following water regimes were evaluated using Completely Randomized Block Design (RCBD) with three replications. Plot size was 3 m x 3 m and there was 0.5 m between plots, blocked by ridges to protect water flowing outside the plot. The method of irrigation was furrow irrigation with furrow spacing of 75 cm, width of 20 cm and depth of 15 cm. The right amount of water was measured by calibrated bucket of known volume. Information on date of water application, depth of irrigation water, rainfall, total number and weight of tubers were collected. Analysis of variance was conducted for the combed data across years using SAS.

Table 1. Description of water regimes applied for the experiment.

	Growth stage/period				Description
	P_1	P_2	P_3	P_4	
Water regimes	25	30	35	40	LGP (in days)
1111	1	1	1	1	Irrigate 100% of CWR
25%	25%	25%	25%	25%	Irrigate 25% of CWR
50%	50%	50%	50%	50%	Irrigate 50% of CWR
75%	75%	75%	75%	75%	Irrigate 75% of CWR
	Stress during one growth stage				
0111 (0= 25%CWR)	0	1	1	1	Stress during P_1
1011 (0= 25%CWR)	1	0	1	1	Stress during P_2
1101 (0= 25%CWR)	1	1	0	1	Stress during P_3
1110 (0= 25%CWR)	1	1	1	0	Stress during P_4

Results and discussion

Effect of deficit irrigation on potato tuber yield

Significantly higher tuber yields were recorded with the application of full amount of the crop water requirement at all stages and 75% water deficit either at initial or last crop growth stage (Table 1). Significantly lower tuber yield was recorded with the application of 25% of the crop water requirement at all crop growth stages. The highest and significant tuber yield reduction (4.38 ton ha^{-1}) was recorded with applying only 25% crop water requirement throughout all growth stages. Tuber yield reductions of 64%, 39% and 28% were recorded with the applications of 25%, 50% and 75% of the total crop water requirement at all stages, respectively. About 35% and 29% tuber yield reductions were also recorded with applying 75% water deficit at the third and second crop growth stages, respectively (Table 1). This was attributed to the fact that adequate watering conditions early in the season lead to the development of an abundant leaf cover and shallow root depth (Bazza, 1999). When a severe stress follows, the crop rapidly depletes the soil water stored in the root zone and wilts before the completion of additional root development at greater soil depth. The above statement also supported by Bazza (1999), on different vegetable crops and for some cereals and he concluded that minimum yield was gained during the full stress, but stressing the crops during initial and final stage of the growing season did not affect the crop yield significantly. It can be concluded that under limited water, it is better to stress the crop during early and end of the season. By doing so, the crop adapts to limited watering conditions with the stress not being severely concentrated in any one-time period.

On the other hand, the amount of water saved was 4670 m^3 ha^{-1} and 3110 m^3 ha^{-1} by applying 25% and 50% of the crop water requirement throughout the growing period, respectively. This reduction in the amount of water led to tremendous tuber yield reduction, 4.38 and 2.65 ton ha^{-1}, respectively. This yield reduction was much higher than the yield reduction observed during stress occurred at the different growing stages. However, applying 75% water deficit at the last growth stage saved about 1670 m^3 ha^{-1} of water with limited effect on tuber yield. This water could irrigate an additional area of about 0.37 ha.

Table 2. Effect of deficit irrigation on the tuber yield and water productivity in potato at Sekota combined across years (2006 and 2007).

Treatments	Tuber yield ($kg\ ha^{-1}$)	Irrigation water applied ($m^3\ ha^{-1}$)	Saved water ($m^3\ ha^{-1}$)	Yield reduction (%)
Irrigate 100% CWR*	6895a$^{£}$	6230	0	0.0
Irrigate 25% of CWR	2511c	1560	4670	64
Irrigate 50% of CWR	4243b	3120	3110	39
Irrigate 75% of CWR	4931b	4680	1550	28
75% deficit at initial stage	6618a	5800	430	4
75% deficit at second stage	4885b	5280	950	29
75% deficit at third stage	4516b	4600	1630	35
75% deficit at last stage	6886a	4560	1670	0.14
CV (%)	16.14		-	-

**Crop water requirement. £Means followed by the same letters are not significantly different at p≤0.05.*

Effect of deficit irrigation on water productivity

The lowest yield reductions were observed when 75% deficit irrigation was applied at the last and initial crop growth stages, respectively (Table 1). However, the yield reduction can be compensated by using the saved water to irrigate additional area. It was observed that

430 and 1670 m^3 water ha^{-1} could be saved by applying deficit irrigation, stressing during initial and last growth stages of the crop, respectively (Table 1). Using the saved water, an extra 0.5 and 2.5 ton ha^{-1} tuber yield of potato could be produced by irrigating more irrigable area (0.07-0.37 ha). The other irrigation regimes were not found economical, as the yield reductions were high and the water saved could not compensate the yield reduction. It is, therefore, advantageous to apply deficit or stress at the initial and maturity stages of the crop to save more water and to irrigate more areas, without significant yield reduction.

Conclusion and Recommendations

Results revealed that high potato yields could be obtained with water stress imposed at the early and late crop stages, provided that adequate watering takes place during the rest of the growth stages. The most critical period for irrigation was the third growth stage. This period coincides with the highest water requirement and the crop cannot withstand water deficit at this stage. It is possible to increase water productivity of the irrigation system by stressing the potato crop at the initial and last growth stages and divert the saved water to increase irrigated area. Considering both yield advantage and water use efficiency, 75% deficit irrigation application only at the fourth growth stage and full irrigation application at other growth stages gave high tuber yield and saved 1670 m^3 ha^{-1} of irrigation water. Thus, 75% deficit application only at the fourth growth stage of potato is recommended.

References

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