

WATER PRODUCTIVITY OF POTATO UNDER IMPROVED IRRIGATION TECHNIQUES IN UZBEKISTAN

Kakhramon Djumaboev¹, J. Mohan Reddy², Carlo Carli³, Tulkun Yuldashev⁴, Oytur Anarbekov⁵ and Davron Eshmuratov⁶

ABSTRACT

Potato is a very important cash crop in Uzbekistan as the government has implemented several measures to increase its production to meet food security as well as to improve its export potential. However, irrigation water demand of potato is much higher than for other crops such as sorghum and maize, which normally consume less water and generate more income. Furrow irrigation is the main irrigation method used to grow potato in Uzbekistan. Introduction of improved irrigation methods could reduce the water used for potato production and provide alternative solutions to improving potato production and income security under water scarce conditions. There are few comparative studies on conventional furrow versus improved irrigation methods for potato production.

This paper explores water productivity of two varieties of potato under four irrigation treatments in Andijan and Ferghana regions of Uzbekistan. At each location, four different irrigation treatments were evaluated. These four treatments were: conventional furrow irrigation (CFI), high frequency furrow irrigation (HFI), partial root zone drying irrigation (PRD), and drip irrigation (Dri). The experimental sites in each study area were established in 2012 on farmer fields. Data on water used and agronomic performance were collected from both study sites to calculate water productivity for each treatment. Analysis of Variance (ANOVA) was used to identify differences in treatments. The results indicate that, overall, high frequency furrow irrigation and drip irrigation treatments performed better than conventional furrow irrigation and partial root drying treatments.

Research findings from this paper are useful for relevant stakeholders in Uzbekistan whose population is highly dependent on irrigated agriculture. Existing water use policies in Uzbekistan do not provide water users incentives for water saving as water delivery for agriculture is highly subsidized by the government resulting in excessive water use. These findings may help reduce unsustainable water use by increasing knowledge of relevant stakeholders including decision makers in order to improve water policies in the region.

1 Researcher/Water Resources Management, Water Management, International Water Management Institute (IWMI). Central Asia Office, Flat No.120, Building No.6, Osiyo Street, Tashkent, 100000, Uzbekistan. E-mail: k.djumaboev@cgiar.org.

2 Professor (Affiliate Faculty) - Irrigation, Department of Civil & Environmental Engineering, Colorado State University, Fort Collins, Colorado, USA. E-mail: mohanreddyi@hotmail.com

3 Manager, Agriculture Division@ SNF-Floerger, France, Former Program Leader International Potato Centre (CIP), Central Asia Office; E-mail: ccarli@snf.fr

4 Consultant, Water Management, International Water Management Institute (IWMI). Central Asia Office, Flat No.120, Building No.6, Osiyo Street, Tashkent, 100000, Uzbekistan. E-mail: tulkun_yuldashev@mail.ru

5 Researcher/ Economist-Social Scientist, International Water Management Institute (IWMI). Central Asia Office, Flat No.120, Building No.6, Osiyo Street, Tashkent, 100000, Uzbekistan. E-mail: o.anarbekov@cgiar.org

6 PhD student, Hydro meteorological Research Institute, 1st Bodomzor Yuli Street 72, Tashkent, 100052, Uzbekistan. E-mail: eshmuratov_d@mail.ru

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1. INTRODUCTION

Potato (*Solanum tuberosum* L.) is cultivated in more than 100 countries, under various climate conditions. In Uzbekistan, potato is a chief cash crop as it is called the “second bread” trailing only wheat and rice in term of consumption (Reddy et al. 2016). The government of Uzbekistan has introduced several measures to increase potato production to improve food security as well as enhance the export potential of the country (Buriev et al. 2013). In 2013, potato was grown on 78,300 hectares for a total production of 2.25 million tons (UzStat, 2014). However, the cost of potato in Uzbekistan is still higher than in neighboring countries (Bobojonov & Aw-Hassan 2014). Hence, there is still a need to increase production in order to develop food security as well as to improve the export potential of the country. However, agricultural production is mainly employed under irrigation in the country, and there is a growing concern about water use inefficiency and water scarcity in Central Asian countries.

Uzbekistan is the most vulnerable of the Central Asian countries with respect to availability of water resources as it has the largest rural population with more than 16 million people, and the highest population density of 77 persons per km² (UzStat, 2019). With an irrigated area of about 4.3 million hectares, Uzbekistan is also the highest agricultural water consumer in Central Asia. Water originates from sources lying outside the country’s borders, a situation that is prone to cause conflicts with neighboring countries whenever water shortages happen. This situation is worsened by global warming and climate change. Available literature suggests that irrigation water availability may decline up to 30% in the future (Chub 2007; Ososkova et al. 2000; Siegfried et al. 2012).

In Uzbekistan, furrow irrigation is the only irrigation method used to grow potato crops (Bekturova & Romanova 2007). A good potato crop requires 400 to 800 mm of water, depending on climatic conditions, soils and duration of the growing season. At a plant density of 40,000 plants per hectare, this corresponds to 100 to 200 liters of water per plant per growing season (Haverkort 1982). In the lowlands of Uzbekistan, up to 9000 m³ ha⁻¹, equivalent to 900 mm, have been recommended by local irrigation specialists (Balashev 1968). Thus irrigation water demand of potato in Uzbekistan is higher when compared to other crops such as sorghum and maize which usually require less water and generate more income under water scarcity conditions in the region (Bobojonov et al. 2013). However, profit from potato is also higher when compared to other crops (Bobojonov et al. 2013). Therefore, there is a very large tradeoff for farmers in crop allocation when there is a high uncertainty about availability of irrigation water during the vegetation period. There is a lack of literature about the profitability of potato production under conditions of deficit irrigation in order to determine returns to potato cultivation under water scarcity conditions. Therefore, there is an urgent need to investigate yield, water productivity and profitability of potato crop under different irrigation regimes. This may contribute to enhancing food security situation in Uzbekistan, particularly under the conditions of increasing population, and growing water scarcity caused by climate change.

Potato is relatively sensitive to soil-water deficit, and to optimize yield total available soil-water should not be depleted by more than 30-50 percent before the next irrigation. There have been some reports on the effects of water stress and irrigation regimes on potato crop in some parts of the world (Fabeiro et al. 2001, Yuan et al. 2003, Onder et al. 2005, Kaur et al. 2005). Drought severity, timing of irrigation and duration of water stress at different potato growing stages influence the crop yield due

to its sparse and shallow root system (Opena & Porter 1999). According to Iqbal et al. (1999) yield response of potato is influenced by the timing of drought, showing a greater sensitivity at early growing stages than during the bulking period, towards maturity. Other researchers indicated that under limited soil water availability occurring at different growth stages, tuber size and quality are influenced as well and that the crop may respond with earlier crop maturity (Karafylidis et al. 1996), less tuber yield and number of tubers per plant (MacKerron & Jefferies 1998, Ojala et al. 1990, Lynch et al. 1995, Karafylidis et al. 1996, Dalla Costa et al. 1997, Yuan et al. 2003). It is still not clear as to what is the optimum irrigation strategy, in terms of timing and magnitude of induced water stress, for potato crop under different levels of water availability scenarios. This is particularly so for the climatic conditions of Fergana Valley of Central Asia, where water availability is unpredictable, dry years are frequent and rainfall variability is very high during vegetation periods. Furthermore, deficit furrow irrigation techniques have not been investigated adequately in potato cultivation to the same extent as for other crops in the region. Therefore, field studies were undertaken Fergana and Andijan Provinces of the Republic of Uzbekistan to study yield and water productivity of the potato crop under different levels of soil-moisture deficit.

2. METHODS

2.1 Description of Site Characteristics and Experimental Layout

The experiment was conducted under farmers' conditions at 'Sarkor' farm in Fergana province (N = 40°19'28", E = 71°50'24") and 'Baht Taronasi' farm in Andijan province (N = 40°30'93", E = 72°17'311") in Uzbekistan in 2012. Both the farmers were chosen for their previous experience in potato cultivation. The nearest meteorological station to both field sites is located in Fergana City, around 300 km from Tashkent, the capital of Uzbekistan. Annual precipitation in 2012 was around 150 mm, with 90% occurring during October through May. The area has high summer temperatures (27–35 °C during June, July and August). During the winter temperatures drop to as low as -5 °C, with an average of -1 °C. Owing to high summer temperatures and low rainfall, evaporation exceeds precipitation during the potato-growing period. This necessitates the use of irrigation to support crop growth. Both soils have a pH value in the range of 8.27 - 8.32, and a low EC value (0.14 - 0.19 dS m⁻¹). Moreover, the soil in Fergana is a silty clay loam with a bulk density of 1.25 g cm⁻³ whereas in Andijan it is a silt loam with a bulk density of 1.48 g cm⁻³. Field slopes were 0.004 and 0.006 in Fergana and Andijan, respectively.

In Sarkor farm planting was done on 17th July 2012 and was harvested on 1st November 2012, whereas in Baht Taronasi farm planting was done on 20th July 2012, and was harvested on 2nd November 2012. In both fields winter wheat was planted during the previous year. The experimental design in both sites was randomized complete block design with one crop variety (Sarnav (CIP397077.16)) and 4 water deficit irrigation treatments with three replications for a total of 1 × 4 × 3 = 24 plots. Well-sprouted seed size tubers of 35-55 mm size were planted at a distance spacing of 0.25 m x 0.70 m (Fergana) and 0.25 m x 0.75 m (Andijan), corresponding to 57,100 and 53,300 plants ha⁻¹, respectively. At each location, four different irrigation technologies were evaluated. The four irrigation treatments were: (T-1) furrow irrigation (every furrow) with normal irrigation scheduling (TIS); (T-2) high frequency furrow irrigation (HFI); (T-3) partial root drying irrigation (PRD); and (T-4) drip irrigation. Treatment T-1 was the control treatment for this trial. Each plot was built as a basin to have a light slope and no water outflow in order to facilitate the calculation of the volume of water applied to each treatment. The amount of water inflow was recorded using 90° V-notch weir. For each weir, a stage-discharge curve was available, which allowed the calculation of the amount of water applied for each

treatment. In Fergana, and precisely in Sarkor farm, plot size was equivalent to 28 m², comprising of four rows per plot and roughly forty plants per row. Therefore, the area of each irrigation treatment was 84 m² (3 x 28 m²), while the total area occupied by the trial was 0.0336 ha. In Andijan, the plot size was equivalent to 27 m². Within each irrigation treatment, there was one variety (Sarnav) replicated thrice. Therefore, the area of each irrigation treatment was 81 m² (3 x 27 m²), and the total area of the trial was 0.0324 ha.

Soil-moisture levels within the plots were monitored using tensiometers, installed at depths of 20 cm and 40 cm, in the middle of 3 randomly selected plots of each irrigation treatment, making sure that there was one tensiometer per each depth and per replication. The tensiometers installed at 20 cm depth were used to decide when to irrigate, whereas the tensiometers installed at 40 cm depth were used to decide the adequacy of the amount of water applied. The average of the readings from 3 tensiometers within each irrigation treatment was used in making irrigation decisions. In addition, Potato yields under different irrigation treatments were also recorded at the end of the season. The volume of irrigation water applied to each irrigation treatment during each irrigation event was measured using Chipoletti weirs. Rainfall amount was not considered in the analyses because it was negligible (2.6 mm) during the crop season. Since each irrigation treatment had six plots, the volume of water applied to each plot was set equal to 1/6 of the total volume of water applied to the entire treatment. Furthermore, since there was no net runoff from each treatment, the volume of water percolated in each plot was equal to the amount of water applied to each plot. The date and the amount of water applied to each irrigation treatment were recorded throughout the crop growing season. All the plots received a pre-season irrigation 3 days before planting so that the soil-moisture content within the rooting depth of 0.50 m was close to field capacity. At the end of the season, potato tubers were harvested only from the two inner rows in order to minimize edge effects from other treatments. The tuber yield was calculated in tons ha⁻¹ by weighing the potatoes harvested in the two inner rows. Yield, water productivity and Irrigation water use efficiency values were then subjected to analyses of variance (ANOVA) tests (Gomez and Gomez, 1984) to check whether there were any significant differences among different irrigation treatments that were appropriate for a randomized complete block design. Effect of irrigation treatments to yield and water productivity was evaluated using the statistical software (Genstat 12th Edition).

3. RESULTS

3.1 Irrigation Water Application Rates under Different Irrigation Treatments

The results recommend that the amount of irrigation water towards potato irrigation in Andijan and Ferghana provinces can be reduced significantly by applying improved irrigation practices such as drip irrigation or high frequency irrigation (Table 1). The number of irrigations applied under TIS, HFI, PRD and Dri treatments was, respectively, seven, seven, seven and eight, and the total seasonal volume of water applied for TIS, HFI, PRD and Dri was, respectively, 93 m³ (5730 m³ ha⁻¹), 61 m³ (3783 m³ ha⁻¹), 81 m³ (5029 m³ ha⁻¹), and 35 m³ (2130 m³ ha⁻¹). The amount of water applied under TIS and PRD treatments during the first irrigation event was significantly higher than the water retention capacity of the soil. Similarly, water for potato irrigation can be reduced by 40%, i.e. from the current 573 mm to 213 mm when drip irrigation is applied and by 35%, i.e. to 378 mm when high frequency irrigation is introduced.

Table 1. Number of irrigations and irrigation amounts applied for different irrigation treatments at Andijan site

Irrigation #	TIS		HFI		PRD		Drl	
	days after planting	m ³	days after planting	m ³	days after planting	m ³	days after planting	m ³
1	16	39.2	11	15.0	11	22.0	13	4.0
2	29	8.8	21	14.0	21	21.8	20	4.0
3	43	10.2	33	9.0	30	9.1	41	4.0
4	53	10.3	46	5.1	46	5.8	48	4.5
5	64	8.7	60	6.3	60	6.5	55	4.5
6	77	7.2	76	6.2	73	8.2	63	4.5
7	88	8.4	85	5.7	84	8.1	75	4.5
8							86	4.5
Total irrigation		92.8		61.3		81.5		34.5
Total irrigation (m ³ ha ⁻¹)		5730		3783		5029		2130

At Fergana, the number of irrigations applied under the TIS, HFI, PRD and Drl treatments was, respectively, six, eight, nine and eight, and the total seasonal volume of water applied for TIS, HFI, PRD and Drl treatments was, respectively, 71 m³ (4198 m³ ha⁻¹), 52 m³ (3065 m³ ha⁻¹), 79 m³ (4688 m³ ha⁻¹), and 33 m³ (1988 m³ ha⁻¹) (Table 3). At this site, irrigation treatments TIS and PRD received much higher volumes than the water retention capacity of the soil at field capacity, resulting in deep percolation losses. Here, the irrigation treatment under PRD received the most seasonal amount of water (4688 m³ ha⁻¹), and the Drl treatment received the least amount of water (1988 m³ ha⁻¹). It is clear that the HFI and Drl treatments for both sites received significantly less water than the seasonal irrigation requirements of the crop, as expected.

Table 2. Number of irrigations and irrigation amounts applied for irrigation treatments in Fergana site

Irrigation #	TIS		HFI		PRD		Drl	
	days after planting	m ³	days after planting	m ³	days after planting	m ³	days after planting	m ³
1	21	14.3	11	8.7	11	10.1	15	3.6
2	34	13.0	21	8.2	21	10.0	21	3.6
3	44	10.3	34	10.7	34	11.3	34	7.2
4	52	10.3	44	4.8	44	8.8	44	3.8
5	63	10.4	52	5.3	52	8.9	54	3.8
6	74	12.4	58	5.5	58	9.4	63	3.8
7			70	4.8	63	9.1	74	3.8
8			87	3.6	70	7.8	87	3.8
9					87	3.4		
Total irrigation		70.5		51.5		78.8		33.4
Total irrigation (m ³ ha ⁻¹)		4198		3065		4688		1988

3.2 Potato Yields, Water Productivity (WP) and Irrigation Water Use Efficiency (IWUE)

In addition, Potato yields under different irrigation treatments were also recorded at the end of the season. The potato yield data for the Andijan and Fergana sites are presented in Table 4. The highest yield was obtained under HFI treatment for Andijan site (26938 kg ha⁻¹) and Fergana site (19595 kg ha⁻¹), whereas the lowest yield of 18296 kg ha⁻¹ was obtained under Drl treatment for Andijan site and 12667 kg ha⁻¹ was obtained under TIS treatment for Fergana site. As expected, there was a large variation in crop yields between different irrigation treatments –HFI and PRD, HFI and Drl. In general, the HFI and PRD irrigation treatments produced much higher yields

than the Drl treatment, which received the least amount of irrigation water. The yields of potato under HFI are already close to the achievable levels at the respective location which suggest that other agronomic practices (such as cultivar, planting date, fertilization, field preparation, etc.) maybe of consideration for achieving even higher yields. Water productivity (yield/ET) and Irrigation water use efficiency (yield/water applied) are good indicators of effectiveness of water usage. Since there was a significant saving of water with no adverse impact on the crop yield, WP increased when irrigation method was changed from traditional irrigation scheduling to drip irrigation and high frequency irrigation method (Table 2). WP increased by 31 and 65% when irrigation method was changed from traditional irrigation scheduling to high frequency, partial root depletion and drip irrigation method respectively.

Table 2. Comparison of yield, WP and irrigation water use efficiency under conventional, high frequency, partial root depletion irrigation and drip irrigation methods for potato in Andijan and Ferghana provinces in Uzbekistan

Treatment	Andijan				Ferghana			
	Irrigation water applied	Yield	Water productivity	Irrigation water use efficiency	Irrigation water applied	Yield	Water productivity	Irrigation water use efficiency
	(mm)	(kg ha ⁻¹)	(kg m ⁻³)	(kg m ⁻³)	(mm)	(kg ha ⁻¹)	(kg m ⁻³)	(kg m ⁻³)
TIS	573	22100	4.87	3.86	419.8	12667	3.42	3.02
HFI	378.3	26938	7.48	7.12	306.5	19595	5.71	6.39
PRD	502.9	20197	5.56	4.02	468.8	17595	4.50	3.75
Drl	213	18296	5.73	8.59	198.8	13262	4.72	6.67

Note: LSD at p = 0.05 were 5120 kg ha⁻¹ for yield and 1.34 kg ha⁻¹ mm⁻¹ for yield and water productivity in Andijan site. LSD at p = 0.05 were 3920 kg ha⁻¹ for yield and 1.03 kg ha⁻¹ mm⁻¹ for yield and water productivity in Ferghana site.

4. CONCLUSIONS

Field trials were conducted at “Sarhor” farm in Andijan province and “Baht” farm in Ferghana province, Uzbekistan to evaluate the performance of potato variety Sarnav under the four irrigation treatments: TIS, HFI, PRD and Drl, with three replications. The crop yield data of different treatments ranged from 12.6 t ha⁻¹ to 26.9 t ha⁻¹, whereas the WP values ranged from 3.42 kg m⁻³ to 7.48 kg m⁻³ and IWUE values ranged from 3.02 kg m⁻³ to 8.59 kg m⁻³. The ANOVA of yield data suggested there were significant differences between treatments. The ANOVA of WP data suggested there was a significant difference between the response of the Drl and TIS treatments and between the TIS and HFI. The results above show that HFI and Drl are the best irrigation option for farmers, and if they cannot afford this option, Partial root depletion is another alternative solution for saving water and obtaining higher cotton yields. The ANOVA of IWUE data suggested there was a significant difference between the response of the Drl and HFI treatments and between HFI and PRD treatments. The drip irrigation and high frequency irrigation treatments enhanced WP and IWUE for SARNAV potato variety in both provinces in Fergana valley. The pilot plot represents 30 percent of irrigated area in Ferghana and Andijan province (178,500 ha). If drip irrigation system or high frequency irrigation is widely adopted by the farmers, large amounts of water can be saved, which then can be diverted to expand agriculture or for other purposes such as supporting ecosystem services. Overall, the HFI and Drl treatments performed better than the TIS treatment.

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