

Irrigation Water Productivity and Potato (*Solanum tuberosum* L.) Yield in Different Planting Methods under Mulched Conditions

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ABSTRACT

To investigate the effect of planting methods i.e. drip irrigated beds (DIB+M), furrow irrigated beds (FIB+M) and ridge (R+M) methods under mulched condition at different irrigation regimes on irrigation water productivity and potato (*Solanum tuberosum* L.) yield, a field experiment was conducted in sandy loam soil at the Research Farm of Department of Soil Science, Punjab Agricultural University, Ludhiana. Three irrigation levels based on IW/PAN-E ratios of 1.2, 1.6 and 2.0 were tested under FIB+M and R+M, while 0.3, 0.4 and 0.5 were tested under DIB+M. The treatments were replicated thrice a time with split plot design. Paddy straw mulch was applied @ 6 t/ha in all the treatments. The potato tuber yield increases with increase in irrigation level for all the methods. The highest mean tuber yield of 26.5 t/ha was recorded in DIB+M at IW/PAN-E 0.5, followed by FIB+M (24.2 t/ha) and R+M (22.6 t/ha) at equivalent IW/PAN-E ratio 2.0. Potato biomass yield was also observed to be highest in DIB+M and least under R+M method. The irrigation water productivity (IWP) was highest under DIB+M followed by FIB+M and least under R+M method. The IWP decreases with increase in irrigation level. The results revealed that DIB+M at IW/PAN-E ratio of 0.5 could successfully be used for potato cultivation with water saving and higher productivity.

Keywords: Mulch, potato, drip, furrow, ridge, bed, IW/PAN-E, water productivity

Comment [W1]: This sentence should be rephrased. R+M is not significantly different from FIB+M

Comment [W2]: R+M is not significantly different from FIB+M

1. INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the most important vegetables in world. Potatoes are sensitive to water stress due to shallow root zone. They are generally planted on raised beds and furrow-irrigated un-mulched conditions. As such, water use efficiency is very low. However, the use of mulch reduces water requirement in potato by 33 % [1]. Drip irrigation is well suited for use with raised bed production cultures [2]. Currently, because of water shortages, farmers have been encouraged to adopt drip irrigation. Irrigation frequency is one of the most important factors in drip irrigation scheduling. Due to the differences in soil moisture and wetting pattern, crop yields may be different when the same quantity of water is applied under different irrigation frequencies. High irrigation frequency might provide desirable conditions for water movement in soil and for uptake by roots [3]. Drip irrigation has a high efficiency for adding water and nutrients to crops. Crop yield can increase through improved water and fertility management and reduced disease and weed pressure. Thus, the main benefits of drip irrigation are that it reduces water use and improves the health of the plant [4]. The implementation of drip irrigation technologies results in net water savings, thereby easing the prevailing water-scarcity problems. The water saving is attained through substantial reduction in losses due to evaporation and inefficient field conveyance and distribution systems. For instance, water application can be reduced by 50 percent through the drip method of irrigation [5]. The highest irrigation water use efficiency was observed with the irrigation regime of 0.80 Ep as compared to 0.60, 1.00 and 1.20 [6]. Drip irrigation system is completely suitable for potato production under sandy land conditions, where it can provide the exact water requirements to the crops. Higher plant height, biomass, shoot water content and potato yield was observed with the treatments which had not suffered from water deficit [6,7,8]. The amount of irrigation water had significant effects on

decreasing the canopy temperature. Total fresh tuber yields and marketable tuber yields (>85 g) increased with increasing amount of irrigation water. The highest yield was obtained at the 1.25 times regime and the total tuber yield was close to the theoretical maximum. Water stress significantly affected the yield and yield parameters of early potato production [9]. Water deficit was an important stress factor in potato cultivation and led to yield decrease [10]. The results detected that irrigation treatments had significant effects on tuber yield, tuber number, tuber weight, tuber larger than 55 mm in size, and tuber number (35-55 mm in size). Water stress led to decrease in tuber yield, tuber weight and tuber number (> 55 mm in size). Tuber-setting stage was the most sensitive stage to water stress and led to the most decrease in yield. Plant height, biomass and tuber yield increased by the increase in irrigation level [6]. The highest tuber yield was obtained in the irrigation regime of 1.20 Ep (Pan Evaporation). A preferable grade of tuber (>28 mm in size) decreased with the decrease in irrigation level from 1.20 to 0.60 Ep. Specific gravity and starch percentage in tuber increased with the increase in irrigation level. Therefore, it could be detected that potatoes should be irrigated at 1.20 Ep to obtain higher yield and better quality. However, if water availability is limited, 0.80 Ep would be most appropriate for sustainable agriculture. The highest total tuber yield (31.6 t/ha) was obtained with micro sprinkler, then drip (29.8 t/ha) and furrow (22.6 t/ha) irrigation systems when irrigation level was 1.20 IW (Irrigation Water): CPE (Cumulative Pan Evaporation) [11]. Potato tuber yield increased with increasing irrigation level from 0.60 to 1.20 IW: CPE, regardless of irrigation system. However, the highest water use efficiency was recorded by 0.80 IW: CPE under micro sprinkler irrigation. Applying 257 and 261 mm of irrigation water attained the best tuber yield under micro sprinkler and drip irrigation systems, respectively. The purpose of this study was to

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understand the effect of different planting methods under mulched condition and irrigation regimes on irrigation water productivity and potato yield.

2. MATERIAL AND METHODS

The study site is located in north-west India with 30°56'N latitude, 70° 52'E longitude and 247 m above mean sea level. The region experiences semi-arid climate with extremely hot during summer and cold during winter. The annual average temperature is 18.7 °C and annual average total precipitation is 700 mm. The soil physico-chemical properties are presented in Table 1. In-situ infiltration rate was measured using double ring infiltrometer method and bulk density was measured using core method. Soil samples were collected from 0-15 and 15-30 cm depths to determine soil chemical characteristics e.g. Available N, P, K, pH, EC and organic carbon (OC) etc. before potato (*Solanum tuberosum* L.) var. Kufri Badshah planting. The treatments consisted of three planting methods {drip irrigated beds (DIB+M), furrow irrigated beds (FIB+M) and ridge (R+M)} with paddy straw mulching @ 6 t/ha and three irrigation regimes i.e., IW/PAN-E ratio of 1.2 (I1), 1.6 (I2) and 2.0 (I3) for FIB+M and R+M, while the equivalent ratio of 0.3 (I1), 0.4 (I2) and 0.5 (I3) were maintained under DIB+M. DIB and FIB were 70 cm wide on which two potato rows were sown at 60 cm apart, while ridges were 30 cm wide and single potato row was sown. The treatments were replicated thrice in split plot design. Crop biomass and tuber yield was recorded separately for each plot and converted into t/ha. Irrigation water productivity was calculated by dividing crop yield with amount of irrigation water applied. Statistical analysis was performed using an analysis of variance with statistical software CPCS1 [12].

3. RESULTS AND DISCUSSION

3.1 Amount of Water Applied and Biomass Yield

Comment [W4]: It is not clear if available concern only N or also P and K? pH , EC and OC should be mentioned in another sentence.

Comment [W5]: Methods of chemical analysis??

After sowing, common irrigation was applied to all the plots for proper crop establishment irrespective of irrigation treatments. Subsequently, the irrigations were applied based on IW/PAN-E ratios. Irrespective of irrigation regimes, minimum water was applied in DIB+M (231 mm) followed by FIB+M (273 mm) and highest water was applied under R+M method (287 mm). However, among different irrigation regimes mean maximum water was applied under I3 i.e. 310 mm followed by I2 (260 mm) and I1 (220 mm) treatments. Faberio et al. [7] found that 597 mm irrigation water was required to reach maximum tuber yield of 45.2 t ha⁻¹. Potato biomass yield was observed to be significantly affected by planting method and irrigation levels (Table 2). Highest yield observed under DIB+M plots was due to higher soil moisture content i.e. around field capacity throughout the crop growing season than other methods. Under FIB+M and R+M methods due to more deep drainage and evaporation losses there are chances of water stress which can hamper plant growth. Potatoes due to shallow root zone suffers more from water stress than any other crop. It is desirable to reduce evaporation losses by the use of mulches. When the plant is unable to meet the evaporative demand of atmosphere, the leaves loose turgor. However, irrespective of planting method maximum mean potato biomass yield (7.5 t/ha) was observed under I3 treatment ~~followed by I2 (7.0 t/ha) and least (6.4 t/ha) and significantly lower~~ under I1 treatment.

Comment [W6]: This way to write yields should be used throughout the manuscript

3.2 Tuber Yield

Tuber yield was observed to be significantly affected by planting methods and irrigation levels (Table 3). The yield in DIB+M was ~~15~~ 9.5% and ~~9~~ 17.2% higher than FIB+M and R+M methods respectively. Potato tuber yield ~~seemed to~~ increase as the irrigation frequency increased. In FIB+M and R+M methods high evaporation losses develop mild water stress and leaf area

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development was slow as compared to drip irrigation. Studies on the response of potato to water stress conclude that even moderate water deficits can result in a low above ground biomass, tuber yield and tuber grade (Hang and Miller [13]; Kashyap and Panda [14]; Steyn et al. [15]). Water stress during the vegetative growth stage reduces leaf area, vine and root expansion, plant height, and delays canopy development. Water stress during tuber initiation can substantially reduce tuber yield. However, irrespective of planting method maximum mean tuber yield (25.5 t/ha) was observed under I3 treatment followed by I2 (24.7 t/ha) and significantly lower least under I1 (23.1 t/ha) treatment. Many researchers have also reported increased tuber yield with irrigation (Shock et al. [16]; Ferreira & Carr [17]; Kashyap & Panda, [14]; Yuan et al., [8]; Kang et al., [18]; Wang et al. [19]).

3.3 Irrigation Water Productivity

Irrigation water productivity (IWP) was observed to be significantly affected by both the planting methods and irrigation levels (Table 4). IWP was observed to higher under DIB+M as compared to and significantly lower under FIB+M and R+M methods due to more tuber yield and lesser irrigation water application. However, irrespective of planting methods maximum mean IWP (t/ha-cm) was observed to be 1.07 in I1 treatment, followed by I2 (0.97) and I3 (0.80) treatments. Erdem et al. (2006) [20] also reported that water use efficiency increased from 4.7 to 6.6 kg m⁻³ for furrow irrigated treatments and from 5.2 to 9.5 kg m⁻³ for drip irrigated treatments. Kang et al. [18] and Onder et al. [9] also registered similar WUE values for potato.

Comment [W8]: This sentence should be rephrased

Comment [W9]: what about IWP

4. CONCLUSION

Water management is a key to obtaining optimum growth without wasting water. Irrigation led to higher soil water content favoring crop evapotranspiration. The application of the effective use of water will go a long way in addressing the global water crisis in future, thereby reducing wastage. Different planting methods under mulched condition and irrigation levels had significant effect on potato tuber yield and irrigation water productivity. Drip irrigated beds with mulch (DIB+M) yielded maximum, while the potato raised on ridges with mulch (R+M) yielded the minimum significantly lower. Potato biomass yield was also observed to be significantly higher under DIB+M than furrow irrigated beds (FIB+M) and R+M method. Irrigation water productivity was highest under DIB+M followed by FIB+M and R+M. It is thus, concluded that DIB+M with IW/PAN-E ratio 0.5 may be adopted for higher production and irrigation water productivity for potato cultivation in areas being similar conditions of experimental site.

Comment [W10]: This statement goes beyond the results obtained.

Comment [W11]: This sentence should be rephrased

Comment [W12]: also FIB+M

Table 1. Physical and chemical properties of the soil collected from experimental site

Soil depth (cm)	pH	OC (%)	Av. N (kg/ ha)	Av. P (kg/ ha)	Av. K (kg/ ha)	BD (Mg/ m ³)	PWP (%)	FC (%)
0-15	7.8	0.42	148.5	53.8	125.8	1.55	8.4	18.6
15-30	7.7	0.31	126.7	42.5	120.2	1.74	8.0	17.8

Comment [W13]: ???

Av. N, P and K are available nitrogen, phosphorus and potassium; BD is bulk density, PWP is permanent wilting point and FC is field capacity

Table 2. Effect of planting methods and irrigation levels on biomass yield (t/ha)

Planting method	Irrigation regimes			
	I1	I2	I3	Mean biomass yield
DIB+M	6.9	7.4	8.1	7.5
FIB+M	6.3	7.0	7.5	6.9
R+M	6.1	6.6	7.0	6.6
<u>Mean</u>	<u>6.4</u>	<u>7.0</u>	<u>7.5</u>	<u>7.0</u>
LSD (<0.05)	Planting methods = 0.4 Irrigation levels = 0.7 Interaction = NS			

DIB+M = Drip irrigated beds with mulch; FIB+M = Furrow irrigated beds with mulch; R+M = Ridge with mulch

I1, I2 and I3 are IW/PAN-E ratios of 1.2, 1.6 and 2.0 respectively, under FIB+M and R+M methods and 0.3, 0.4 and 0.5 under DIB+M method.

Table 3.Effect of planting methods and irrigation levels on tuber yield (t/ha)

Planting methods	Irrigation regimes			
	I1	I2	I3	Mean tuber yield
DIB+M	25.1	26.8	27.7	26.5
FIB+M	22.8	24.6	25.3	24.2
R+M	21.4	22.8	23.6	22.6
<u>Mean</u>				
LSD (<0.05)	Planting methods = 1.7 Irrigation regimes = 2.1 Interaction = NS			

DIB+M = Drip irrigated beds with mulch; FIB+M = Furrow irrigated beds with mulch; R+M = Ridge with mulch; Whereas, I1, I2 and I3 are IW/PAN-E ratios of 1.2, 1.6 and 2.0 respectively, under FIB+M and R+M methods and 0.3, 0.4 and 0.5 under DIB+M method.

Table 4: Irrigation water productivity (t/ha-cm) under different planting methods and irrigation regimes

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Planting methods	Irrigation regimes			
	I1	I2	I3	Mean
DIB+M	1.3	1.2	1.0	1.2
FIB+M	1.0	0.9	0.8	0.9
R+M	0.9	0.8	0.7	0.8
<u>Mean</u>				

LSD (<0.05)	Planting methods = 0.2 Irrigation regimes = 0.2 Interaction = NS
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DIB+M = Drip irrigated beds with mulch; FIB+M = Furrow irrigated beds with mulch; R+M = Ridge with mulch; Whereas, I1, I2 and I3 are IW/PAN-E ratios of 1.2, 1.6 and 2.0 respectively, under FIB+M and R+M methods and 0.3, 0.4 and 0.5 under DIB+M method.

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