



Water production functions for potato (*Solanum tuberosum*) under different irrigation methods

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Received: 7 November 2012; Revised accepted: 10 January 2014

ABSTRACT

A field experiment was conducted at research farm of Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra during *rabi* season of 2006 to 2008, to develop water production functions for potato (*Solanum tuberosum*) under different irrigation systems, viz. sprinkler, microsprinkler, drip and surface irrigation system. Each irrigation method except drip was combined with 5 irrigation regimes, i.e. IW/CPE ratio of 1.40, 1.20, 1.00, 0.80 and 0.60. In drip, variable wetted area factors, viz. 1.30, 1.10, 0.90, 0.70 and 0.50 were applied as irrigation regimes. The sprinkler method was found superior to all other methods in terms of tuber and haulm yield, water use and fertilizer use efficiency. Potato tuber yield increased with increasing irrigation level from 0.60 to 1.20 IW/CPE (in drip 0.5 to 1.10 wetted area) and then decreased at 1.4 IW/CPE ratio (in drip 1.30 wetted area) in all the irrigation methods. However, haulm yield of potato was found highest in 1.4 IW/CPE ratio. The highest water-use efficiency (7.72 q/ha-cm) was recorded with 0.50 wetted area treatment in drip irrigated plots. The second order quadratic water production functions developed to estimate potato yield were used to find optimum depth of irrigation under different methods of irrigation. For sprinkler and microsprinkler methods 3.50 cm depth of irrigation at 25 mm CPE and for surface 6.00 cm depth of irrigation at 50 mm CPE was found optimum. For drip method of irrigation wetted area factor of 0.90 was found optimum.

Key words : Drip, Irrigation regimes, Potato yield, Sprinkler, Surface method. Water production function

Presently, only 17% net sown area is irrigated in the state of Maharashtra as against 40% of the total cultivable area under irrigation in the country. The ever increasing population, urbanization and industrialization have reduced the share of water for agriculture. The western part of state has relatively well developed surface and ground water resources ensuring availability of irrigation water throughout the year. However, due to large scale cultivation of high water consuming annual crops like sugarcane and banana, the water availability is proving to be inadequate. It is also observed that, in many areas excess irrigation is practiced which ultimately affects the yield as well as the productivity of soil (Pawar *et al.* 2002). It is therefore imperative that the available quantum of irrigation water is used judiciously employing efficient irrigation methods and adopting optimum irrigation regimes.

In this context, the state is promoting adoption of micro-irrigation methods through subsidizing its cost to the farmers. Economic growth of the country has resulted in demand for

vegetables and farmers have responded by shifting from crops like sugarcane to remunerative vegetable crops like potato. Currently the state relies on other states to meet its demand for this tuber crop. In fact the country also depends on imports from Bhutan. Therefore it could become a rewarding crop. Shekhawat (2001) has opined that potato (*Solanum tuberosum* L.) cultivation would be a possible alternative to increase the farm income, if efficient and reliable irrigation management strategies are adopted. Potato is an important crop that requires higher and nearly constant water supply for proper growth. Water deficit results in tuber yield reduction, decreased number of leaves, decline in processing grade and post harvest attributes, leaf area, plant height, ground coverage and tuber number (Kaur *et al.* 2005, Sharma *et al.* 2011). However, the extent to which the crop productivity is affected depends largely on the stage of development at which the plant encounters the water deficit (Singh *et al.* 2005, Kumar *et al.* 2007). Therefore, many times for potato crop water-yield relationship is quite complex and it not only depends upon total water supplied during growing season but also on its allocation throughout the period (Kumar Satyendra *et al.* 2009).

Thus, information is needed to guide farmers when and

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how much to irrigate with the use of modern irrigation systems coupled with suitable irrigation schedule. Thus, water production functions need to be derived for the crop so that, the available water resources can be used more effectively producing more yields. In view of this, the study on the response of potato to different irrigation methods; irrigation regimes and to develop the water production functions for potato under different irrigation methods was undertaken.

MATERIALS AND METHODS

The field experiment was carried out at research farm of Inter faculty Department of Irrigation Water Management, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra (19° 47'N latitude and 74°39' E longitude; altitude 500 meters above mean sea level) during three consecutive seasons from 2006 to 2008. The site lies in semiarid area with mean rainfall of 520 mm which is mostly concentrated during the monsoon months from June to September. The distribution of rainfall is erratic and uncertain. The soil is clay loam with pH 8.37 and electrical conductivity of 0.79 dS/m. The textural composition of the soil has 29.8% clay, 37.0% loam and 33.0% sand and the bulk density of soil (0–45 cm) is 1.28 g/cc. The basic rate of infiltration of the soil is 1.3 cm/hour. The soil moisture content in 0–45 cm soil layer at field capacity, permanent wilting point and available soil moisture was 28.36, 14.17 and 14.19%, respectively.

The experiment comprised twenty treatments, viz. four irrigation methods (overhead sprinkler, microsprinkler, drip and surface methods) and five irrigation regimes (irrigation water to cumulative pan evaporation ratio, IW/CPE 0.6, 0.8, 1.0, 1.2, 1.4) arranged in split plot design. In drip method of irrigation, irrigation regimes were considered as variable wetted area factors, viz. 1.30, 1.10, 0.90, 0.70 and 0.50. All

the treatments were replicated four times and repeated for three years.

The potato cv. 'Kufri Jyoti' was planted on ridges and furrows with 60 cm row to row and 20 cm plant to plant spacing under overhead sprinkler, microsprinkler, drip and furrow irrigation systems. The area of each experimental plot was 144 m² (12 m × 12 m). A buffer zone spacing as per requirement was provided between the plots. The planting was done in October – November during all the three years and recommended dose of fertilizer (120:60:120 kg N, P₂O₅ and K₂O per ha) was applied as per schedule during crop period. After planting a common irrigation was applied to all the treatments and then the irrigation systems were laid as per the details given in Table 1. The overhead sprinklers with 1200 lph discharge were installed at a spacing of 12 m × 12 m whereas; the microsprinklers of discharge of 65 lph and 45 cm stake height were installed at 2 m × 2 m. In drip method of irrigation, 16 mm linear low density polyethylene (LLDPE) drip laterals were laid at a spacing of 1.2 m with 4 lph emitters fixed at a distance of 0.60 m.

Class-A open pan evaporimeter was located at a site adjacent to the experimental area with moderate grass cover to estimate the pan evaporation. The irrigations were scheduled using IW/CPE ratio criteria with fixed CPE of 25 mm in overhead sprinkler and microsprinkler and 50 mm in case of surface irrigation system (Table 1). In drip method of irrigation, the quantity of irrigation water calculated using pan evaporation, pan factor (0.8), crop coefficients (FAO 56) and variable wetted area factors applied on every second day (Allen *et al.* 1998). Crop was harvested after 12 weeks of planting to estimate fresh tuber yield. The analysis of variance (ANOVA) was performed to differentiate the treatment effects. Least significant difference (LSD) test was used to

Table 1 The details of irrigation systems used for potato

Aspect	Sprinkler	Micro- sprinkler	Drip	Surface
Lateral spacing, m	12	2	1.2	
Emitter/nozzle spacing, m	12	2	0.6	
Emitter/nozzle discharge	0.6 to 1.41 cm/h	1.62 cm/hr	4 lph	
Irrigation scheduling	25 mm CPE	25 mm CPE	Alternate day	50 mm CPE
Depth of irrigation during each irrigation, (cm)				
T ₁	3.50	3.50	0.50 Wa*	7.0
T ₂	3.00	3.00	0.70 Wa	6.0
T ₃	2.50	2.50	0.90 Wa	5.0
T ₄	2.00	2.00	1.10 Wa	4.0
T ₅	1.50	1.50	1.30 Wa	3.0
Total depth of irrigation, cm (average of three years)				
T ₁	40.07	40.07	28.74	40.07
T ₂	33.44	33.44	22.95	33.44
T ₃	27.04	27.04	20.12	27.04
T ₄	23.93	23.93	17.38	23.93
T ₅	17.50	17.50	13.82	17.50

* W_a Wetted area factor

determine whether differences exist between certain comparisons. The probability level for determination of significance was 0.05.

The water production functions were established between tuber yield of potato with actual water applied for each irrigation methods and their scheduling. Mathematically the function may be expressed as:

$$Y = F(X)$$

Where, Y is the potential tuber yield of potato and X is represented by actual depth of irrigation water applied (IW).

RESULTS AND DISCUSSION

Potato tuber yield

The potato tuber yield data pooled over three years (2006-2008) presented in Table 2 indicated that, the advanced methods of irrigation such as sprinkler, microsprinkler and drip produced higher tuber yield (21.87, 19.57 and 15.90 tonnes/ha respectively) as compared to conventional method of irrigation (14.11 tonnes/ha). However, difference in tuber yield obtained under drip and surface irrigation system was statistically non-significant. It was observed that, the potato yields were 54.86, 38.63 and 12.59 per cent more in sprinkler, microsprinkler and drip method respectively than that of conventional method. The reduction in tuber yield was recorded due to reduction in mean tuber weight under water stress condition. Satyendra Kumar *et al.* (2007) also reported decrease in tuber weight with decreased irrigation water.

Comparison of irrigation regimes showed a consistent increase in potato tuber yield with increasing irrigation from regime no. 5 to regime no. 2 in all irrigation methods (Table 2). Yield increased from 13.03 tonnes/ha under 0.60 IW/CPE irrigation schedule (0.50 wetted area in drip) to a maximum of 20.90 tonnes/ha with irrigation scheduling of 1.20 IW/

CPE (1.10 wetted area in drip). Significant reduction in yield was observed under all lower regimes with water saving to some extent. The lowest tuber yield recorded at 0.60 IW/CPE under furrow irrigation might be due to water stress experienced by the crop. Patel and Patel (2000) also observed significantly higher potato yield under sprinkler irrigation applied at 1.6 IW/CPE ratio. However, irrigation systems and irrigation scheduling interaction effect on potato yield was found non-significant.

It was observed that frequent irrigation with sprinkler and microsprinkler systems washed the leaf canopy and minimized the whitefly infestation (visual observation) as compared to drip and surface irrigated crop. These findings are in accordance with Name Singh *et al.* (2005) who reported better performance of sprinkler irrigation in potato crop as compared to drip irrigation system, and recorded higher yield. Further, sprinkler irrigation system might have helped the crop by lowering the temperature (Tuberization stage in December) by sprinkling water droplets on the leaves of the plant, helped in better growth and higher potato yield as compared to conventional method. Sharma *et al.* (2012) also reported that sprinkler irrigation manipulated the hydrothermal regimes of soil which help in better growth and development of plant.

Haulm yield

Sprinkler irrigation system had significant effect on haulm yield of potato (Table 2). Haulm yield was significantly higher in sprinkler than surface irrigated plots however, under micro sprinkler, drip and surface irrigation the haulm yields were at par with each other. The study also revealed increase in haulm yield with increasing irrigation levels which is supported by the work of Kumar *et al.* (2007). The interactions between irrigation system and scheduling were found non-significant.

Table 2 Potato tuber and haulm yields as affected by various irrigation systems and regimes.

Treatment	Potato tubers, yield (tonnes/ha)				Haulm yield (tonnes/ha)			
	2006	2007	2008	Pooled Mean	2006	2007	2008	Pooled Mean
<i>Irrigation systems</i>								
Sprinkler	23.13	19.07	23.38	21.87	1.30	1.16	1.68	1.51
Micro- sprinkler	22.55	17.48	18.70	19.57	1.23	0.94	1.24	1.13
Drip	16.61	14.90	16.09	15.90	1.12	0.86	1.07	1.02
Surface	15.29	12.88	14.11	14.12	1.08	0.73	1.15	0.99
LSD (P=0.05)	2.57	2.67	2.29	2.17	0.21	0.17	0.15	0.20
<i>Irrigation regimes</i>								
I ₁	23.41	17.61	20.85	20.59	1.56	1.01	1.42	1.33
I ₂	23.13	18.90	20.84	20.90	1.50	1.08	1.39	1.32
I ₃	20.83	16.88	18.35	18.44	1.29	0.96	1.40	1.20
I ₄	17.42	14.81	16.76	16.37	0.98	0.82	1.13	0.98
I ₅	12.26	12.77	14.05	13.03	0.73	0.76	1.11	0.87
LSD (P=0.05)	1.19	1.26	1.05	2.71	0.07	0.07	0.12	0.22

Water use efficiency

Considering the average depth of water applied under each irrigation method irrespective of moisture regime, it was found that sprinkler and microsprinkler resulted into 55 and 38 per cent increase in yield, respectively, without saving any water as compared to surface method of irrigation (Table 3). Whereas, drip method produced 12 per cent more yield with 27 per cent water saving as compared to surface method. Among different irrigation systems, sprinkler system recorded higher water-use efficiency (WUE) than microsprinkler, drip and furrow irrigation due to higher crop yield with less expense of water. Different irrigation regimes influenced irrigation WUE of potato. Table 3 shows an increase in WUE with decline in irrigation regimes. The maximum WUE at 0.60 IW/CPE reveals less water expense under this irrigation regime but tuber yield was decreased up to 37% as compared to 1.2 IW/CPE ratio. Satyendra Kumar *et al.* (2009) also observed variation in water-use efficiency with variable irrigation for potato. Interactions between irrigation system and scheduling were found non-significant.

Water production functions

To establish yield response of potato to irrigation water applied, the water production functions under different methods of irrigation were developed for three years pooled data. The linear, second order polynomial, power, exponential, and logarithmic relationships were tried, out of which second order polynomial relationship (Fig 1) fitted well for all the

irrigation methods. The following functions were fitted for different irrigation systems.

Sprinkler method

$$Y = - 0.010 X^2 + 1.077 X$$

$$R^2 = 0.97$$

Microsprinkler method

$$Y = - 0.010X^2 + 1.001 X$$

$$R^2 = 0.99$$

Drip method

$$Y = - 0.022 X^2 + 1.259 X$$

$$R^2 = 0.79$$

Surface method

$$Y = - 0.010 X^2 + 0.808 X$$

$$R^2 = 0.92$$

where, Y, tuber yield (tonnes/ha); X, depth of water applied (cm).

On comparing observed and calculated potato yields (Table 4), it was revealed that, the yield values obtained from water production functions varied 0 to 8 per cent from the observed values. It indicates that, the water production functions developed for potato can be used to predict the response of tuber yield to quantity of water applied under different irrigation systems. The water production functions revealed that for sprinkler and micro-sprinkler method of irrigation the yield of potato as 28.48 and 24.58 tonnes/ha, respectively can be obtained at total irrigation depth(s) of 53 and 49 cm respectively and further application of water will result in reduction in the yield. However, potential yield

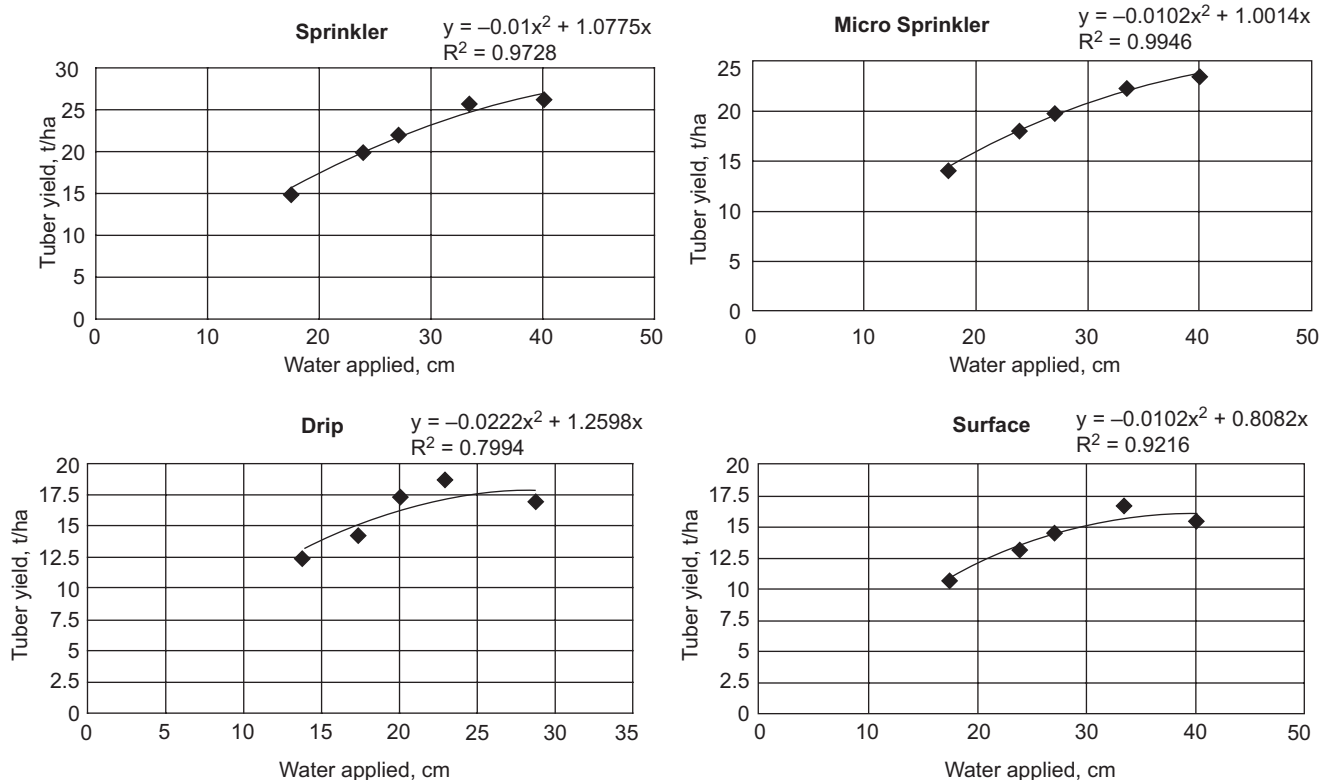


Fig 1 Water production functions for potato under different irrigation methods.

Table 3 Potato yield, water applied and WUE under different irrigation systems for the years 2006 to 2008 (Average of three years) .

Treatment	Potato tuber yield, tonnes/ha	Total water applied, cm	WUE q/ha-cm	Water saving (%)	Increase/decrease in yield (%)
<i>Irrigation systems</i>					
Sprinkler	21.87	28.40	7.70		54.86*
Micro- sprinkler	19.57	28.40	6.89		38.63*
Drip	15.90	20.60	7.72	27.46	12.59*
Surface	14.12	28.40	5.01		
LSD (P=0.05)	2.17				
<i>Irrigation regimes</i>					
I ₁	20.59	37.24	7.17		0.67**
I ₂	20.90	30.82	9.05	17.25***	
I ₃	18.44	25.31	9.29	32.04***	9.97**
I ₄	16.37	22.29	9.40	40.14***	21.34**
I ₅	13.03	16.58	9.42	55.48***	37.28**
LSD (P=0.05)	2.71				

* Increase in yield over surface, ** Decrease in yield over I₂, *** Water saving over I₁

Table 4 Observed and calculated potato yields by using water production functions.

Irri. method	Function	Water applied (cm)	Yield (tonnes/ha)		Deviation	
			Cal.	Actual	tonnes/ha	%
Sprinkler	$Y = -0.010 X^2 + 1.077 X$ $R^2 = 0.97$	40.07	27.13	26.38	0.75	2.84
		33.44	24.86	25.86	-1.00	-3.88
		27.04	21.83	22.16	-0.33	-1.49
		23.93	20.06	19.97	0.09	0.47
		17.50	15.80	14.96	0.84	5.60
Microsprinkler	$Y = -0.010 X^2 + 1.001 X$ $R^2 = 0.99$	40.07	23.75	23.50	0.25	1.06
		33.44	22.08	22.40	-0.32	-1.42
		27.04	19.62	19.80	-0.18	-0.91
		23.93	18.12	18.09	0.03	0.18
		17.50	14.40	14.08	0.32	2.28
Drip	$Y = -0.022 X^2 + 1.259 X$ $R^2 = 0.79$	28.74	17.87	16.99	0.88	5.18
		22.95	17.22	18.63	-1.41	-7.57
		20.12	16.36	17.29	-0.93	-5.38
		17.38	15.19	14.24	0.95	6.67
		13.82	13.17	12.34	0.83	6.73
Surface	$Y = -0.010 X^2 + 0.808 X$ $R^2 = 0.92$	40.07	16.01	15.50	0.51	3.27
		33.44	15.62	16.72	-1.10	-6.58
		27.04	14.40	14.51	-0.11	-0.79
		23.93	13.50	13.17	0.33	2.50
		17.50	11.02	10.72	0.30	2.80

levels (Table 4) and yield levels at regime 1 were statistically on par and hence, regime-1 (application of 3.5 cm of water at 25 mm CPE) can be considered as optimum for potato under sprinkler and micro-sprinklers. Under drip and surface method of irrigation, maximum potato yield (18.63 and 16.72 tonnes/ha) was obtained at irrigation regimes no. 2 (1.10 wetted area factor and 6.0 cm depth at 50 mm CPE) but in drip method, as the yields under regime no. 2 and 3 were on par, the irrigation regime no. 3 (0.90 as wetted area factor)

can be considered as optimum. In surface irrigation method regime no. 2 was found optimum.

The sprinkler irrigation method was found superior to other methods for potato in terms of increased productivity (21.87 tonnes/ha) and higher WUE (7.70 q/ha-cm). The water production functions developed for potato are useful in finding optimum depth of irrigation to obtain potential yield under different methods of irrigation. The study indicated highest yield of potato can be obtained with irrigation at 1.20

IW/CPE under sprinkler and microsprinkler scheduled at 25 mm CPE and surface irrigation method scheduled at 50 mm CPE. For drip method of irrigation wetted area factor of 0.90 was found optimum.

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