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Yield and quality attributes of potato (*Solanum tuberosum* L.) under different irrigation methods and regimes

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ABSTRACT

Potato (*Solanum tuberosum* L.) is sensitive to amounts of irrigation water available. Tuber yields can be adversely affected by poor water management practices. Field experiments were carried out from 2012 to 2014 to evaluate the influence of sprinkler, microsprinkler, drip and surface irrigation methods, and irrigation regimes on growth, yield and quality attributes of potato. Sprinkler, microsprinkler and surface irrigation scheduled was with 1.40, 1.20, 1.00, 0.80 and 0.60 IW/CPE ratios. For drip irrigation wetted area factors of 1.30, 1.10, 0.90, 0.70 and 0.50 were applied as irrigation regimes. Sprinkler, microsprinkler and drip irrigation produced 53.62, 37.53 and 11.74%, respectively, more tuber yield than surface irrigation. Plant height and tuber yield increased with increase in irrigation regime and was highest with irrigation at 1.2 IW/CPE ratio in sprinkler, microsprinkler and surface method, and with 1.10 wetted area factor for drip irrigation. Tuber size varied with irrigation method and regime. Sprinkler and microsprinkler produced the most large size tubers; drip irrigation produced the most medium size tubers. Preferable grade of tuber (>100 g size) decreased with decrease in irrigation regime from 1.2 IW/CPE to 0.6 IW/CPE. The best irrigation water-use efficiency was for drip irrigation, 7.72 q $ha^{-1}cm^{-1}$) with irrigation regime 0.6 IW/CPE which saved 55% more water but recorded 37% less yield than irrigation regime 1.2 IW/CPE. Potato should be irrigated at 1.2 IW/CPE ratio under sprinklers and microsprinklers at 25 mm CPE. For drip method, irrigation at 0.90 wetted area factor would be appropriate for higher yield and better quality of potato.

Keywords: *Solanum tuberosum*, drip irrigation, microsprinkler, sprinkler, tuber size, tuber yield.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is a popular crop throughout the world. Presently world production is about 388.19 million tonnes fresh tubers from an area of 19.33 million ha of potato. India is a major potato growing country in the world with 2.18 million-hectare area under cultivation with total production of 48.60 million tonnes (Rana and Anwer, 2018). However, average potato yield in India is 22.3 t ha^{-1}, which is only half of that in the other parts of world. Growth in the production of potato in India has largely been due to expansion of area rather than increase in productivity. Improper water scheduling is one of the main factors limiting productivity of potato. The difference between potential and realizable yields may be minimized by use of proper irrigation methods and scheduling matching soil characteristics and crop water needs (Rana *et al.,* 2010; Bhardwaj *et al.*, 2015; Dingre and Pawar, 2020).

Potato requires high and nearly constant soil matric potential along with high soil oxygen diffusion rate, and optimal nutrients for proper growth (Bhardwaj *et al.*, 2015). Potato yield is adversely affected due to moisture deficit because it has a sparse root system with approximately 85% of

root mass concentrated in the upper 0.3 m soil layer (Opena and Porter, 1999). Water deficit or excess results in reduced water use efficiency and affects tuber yield (Minhas and Bansal, 1991; Kumar and Minhas, 1999). The extent to which crop productivity is affected due to water related limitations depends on the stage of development (Kashyap and Panda, 2002).

Irrigation scheduling bears special importance besides total water availability. Need based application saves water, and crop also does not suffer (Singh *et al*., 2014; Singh *et al*., 2016a; Singh *et al*., 2016b; Singh *et al*., 2018). Indiscriminate use of water through conventional furrow irrigation with low application and distribution efficiency is a serious threat to available water resources, and it results in reduced yields due to over or deficit irrigation. The amount and schedule of irrigation water application should be such that there is a little fluctuation is the soil moisture content in the root zone (Kumar *et al.,* 2008). Use of modern irrigation systems coupled with appropriate irrigation scheduling can increase yield and quality of potato tubers. Drip or sprinkler irrigation is considered to be a better option over traditional flooding irrigation methods for yield and economics of potato crop (Pawar *et al.,* 2002; Pawar and Dingre, 2014). The suitability of sprinkler or microsprinkler irrigation as affected by irrigation schedule for potato cultivation is not clear. The investigation was undertaken to evaluate response of potato to irrigation method and schedule.

MATERIALS AND METHODS

The experiments were carried out during 2012, 2013 and 2014 (October-January) at the 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 m above mean sea level). The site was semi-arid, mean rainfall of 520 mm, mostly concentrated during the months of June to September, with an erratic and uncertain distribution. The soil was clay loam; 29.8% clay, 37.0% loam, 33.0% sand, bulk density 1.28 gcc^{-1}. The basic rate of infiltration of the soil was 1.3 cm h^{-1}. Soil moisture content in the 0-45 cm layer at field capacity, permanent wilting point, and available soil moisture on dry weight basis (w/w), was 28.36, 14.17 and 14.19%, respectively.

The experiment was arranged in split-plot design with the irrigation methods overhead sprinkler, microsprinkler, drip and furrow irrigation as main plots and the irrigation regimes 0.6, 0.8, 1.0, 1.2, 1.4 IW/CPE as sub-plots. For drip irrigation, the regimes were based on variable wetted area factors *viz*. 1.30, 1.10, 0.90, 0.70 and 0.50. All treatments were replicated 4 times. Cow manure @ 10 t ha^{-1} was applied prior to field preparation. Water soluble fertilizers were applied @ 120 kg ha^{-1} of N from urea, 60 kg ha^{-1} of P_2O_5 and 120 kg ha^{-1} of K_2O (recommended dose) were applied through fertigation as described by Pawar and Dingre (2014). Cut tubers of potato variety 'Kufri Jyoti 'treated with pesticides was planted by hand on ridges at a spacing of 60 × 20 cm in plots measuring 12 × 12 m. After planting a common irrigation was applied to all treatments and then the irrigation systems were imposed.

Overhead sprinklers with nozzles having 1200 Lh^{-1} discharge were spaced 12 × 12 m apart. Micro-sprinklers having discharge of 90 Lh^{-1} were installed at were spaced 3 × 3 m apart. For drip irrigation, a 16 mm LLDPE drip lateral was laid at a spacing of 1.2 m with 4 Lh^{-1} emitters fixed at a distance of 0.60 m. Irrigations were scheduled with fixed Cumulative Pan Evaporation of 25 mm for overhead and microsprinklers and 50 mm for the furrow irrigation (Pawar and Dingre, 2014). For drip irrigation, the quantity of irrigation water was calculated using pan evaporation, pan factor (0.8), crop coefficients and variable wetted area factors applied on every second day (Allen *et al.,* 1994).

Plant height was measured to the highest point of the shoot. Tubers were harvested at 12 weeks after planting for fresh tuber yield. Tubers were classified as large (>100 g), medium (50-100 g), and small (<50 g) size, and green potato.

The data were subjected to analysis of variance using DRYSOFT statistical package. If an interaction was significant it was used to explain the results. If interactions were not significant means were separated with least significant difference at 5 % level of significance (P = 0.05). The pooled analysis was done for all important characters of the study (Panse and Sukhatme, 1995).

RESULTS AND DISCUSSION

Plant height and number of tubers

The plant height was found maximum in sprinkler method of irrigation. The height in sprinkler, microsprinkler and drip was significantly

superior over conventional method of irrigation. Irrespective of irrigation methods, the plant height of potato increased with increase in irrigation regime from I_5 to I_1 irrigation regimes (Table 1). Plant height was statistically at par when crop was subjected to I_2 and I_1 irrigation regime but irrigation at I_4 and I_5 recorded significant reduction.

Table 1. Total no. of tubers/ plant and plant height as affected by various treatments (pooled means)

Treatment	Total no. of tubers/plant	Plant height (cm)
Irrigation system		
Sprinkler	3.72	47.95
Micro-sprinkler	3.98	45.37
Drip	4.36	42.47
Surface	4.07	38.00
C.D. at 5 %	0.39	1.43
Irrigation regimes		
I_1	4.26	46.24
I_2	4.79	46.16
I_3	3.98	43.12
I_4	3.95	41.53
I_5	3.75	40.20
C.D. at 5%	0.46	1.50

Total number of tubers per plant differed significantly among the irrigation methods and found maximum in drip method (Table 1). Total number of tubers plant^{-1} was significantly lower with I_5, I_4 and I_3 irrigation than the other regimes. Higher number of tubers plant^{-1} at I_2 irrigation regime was recorded due to better vegetative growth. The difference in plant growth parameters with irrigation regimes was mainly due to the variation in available soil moisture. Kumar *et al.,* (2007) have also reported that water stress decreases plant growth of potato.

Potato tuber yield

The potato tuber yield data of three years (2012, 2013 and 2014) under different irrigation method and irrigation regimes are presented in Table 2. The sprinkler, microsprinkler and drip method of irrigation produced significantly higher tuber yield (21.86, 19.57 and 15.90 t ha^{-1} respectively) as compared to conventional method of irrigation (14.12 t ha^{-1}). However, difference in tuber yield

Table 2. Potato tuber as affected by different irrigation methodsand regimes.

Aspect	Potato tuber yield (t ha^{-1})			
	2012	2013	2014	Pooled Mean
Sprinkler				
1.4 IW/CPE	30.05	21.74	27.35	26.38
1.2 IW/CPE	29.90	21.07	26.61	25.86
1.0 IW/CPE	22.71	19.89	23.87	22.16
0.8 IW/CPE	20.66	17.23	22.01	19.97
0.6 IW/CPE	12.33	15.44	17.10	14.96
Average	23.13	19.07	23.38	21.86
Micro-sprinkler				
1.4 IW/CPE	28.31	20.08	22.11	23.50
1.2 IW/CPE	27.21	19.22	20.78	22.40
1.0 IW/CPE	23.00	17.27	19.13	19.80
0.8 IW/CPE	19.88	16.60	17.80	18.09
0.6 IW/CPE	14.33	14.24	13.68	14.08
Average	22.55	17.48	18.70	19.57
Drip				
1.30 W_a	17.21	14.87	18.89	16.99
1.10 W_a	17.89	18.25	18.84	18.63
0.90 W_a	19.05	17.03	15.80	17.29
0.70 W_a	15.28	13.49	13.95	14.24
0.50 W_a	12.73	10.87	13.42	12.34
Average	16.61	14.90	16.09	15.90
Surface				
1.4 IW/CPE	17.77	13.71	15.03	15.50
1.2 IW/CPE	18.61	15.49	16.73	16.72
1.0 IW/CPE	16.00	13.31	14.57	14.51
0.8 IW/CPE	13.86	12.37	13.29	13.17
0.6 IW/CPE	9.65	10.53	11.97	10.72
Average	15.29	12.88	14.11	14.12
C.D. at 5 %	2.57	2.67	2.29	2.17

obtained under drip irrigation systems was statistically non-significant, but higher than conventional method of irrigation. In sprinkler, microsprinkler and drip method the potato yields were 54.86, 38.63 and 12.59 % more than conventional method of irrigation respectively (Table 2). The reduction in tuber yield was recorded due to reduction in mean tuber weight under water stress condition.

Comparison of irrigation regimes showed a consistent increase in potato tuber yield with increasing irrigation from I_5 to I_2 in all irrigation methods (Table 2). Yield increased from 10.72 t ha^{-1} under 0.60 IW/CPE irrigation schedule in surface irrigation to a maximum of 26.38 t ha^{-1} in sprinkler irrigation system with irrigation scheduling at 1.4 IW/CPE (Table 2). The lowest tuber yield recorded at I_5 regime under surface irrigation might be due to water stress experienced by the crop. Patel and Patel (2000) reported decrease in tuber weight with decreased irrigation water. However, irrigation systems and irrigation scheduling interaction effects on potato yield was found non-significant.

The yield data presented in Table 2 is analyzed using randomized block design in order to compare the individual treatments with each other and it revealed some interesting findings. The comparison of the tuber yields under sprinkler method and surface method are of some practical utilities. The maximum tuber yield of 16.72 t ha^{-1} was obtained under surface method of irrigation when 6 cm at every 50 mm (1.2 IW/CPE) was applied. The tuber yields under sprinkler method with irrigation regime no. I_1 (26.38 t ha^{-1}), I_2 (25.86 t ha^{-1}), I_3 (22.16 t ha^{-1}) and I_4 (19.97 t ha^{-1}) were statistically significant over maximum yield under surface method of irrigation. When yield levels under sprinkler method of irrigation using irrigation regime I_4, I_3, and I_2 compared with maximum yield under surface irrigation, it revealed that increase in potato yield by 19.4% with 28.4% water saving, 32.5% with 19.1% water saving and 57% without saving any water can be obtained respectively. Findings are in accordance with Name Singh *et. al.*, (2005) who reported better performance of sprinkler irrigation in potato crop as compared to drip and surface irrigation system.

Tuber size distribution

The potato tuber size was found to be varied considerably with irrigation methods and irrigation regimes (Table 3). The data pooled over three years revealed that, the proportion of large size tubers (more than 100 g weight) in terms of weight and numbers were maximum under sprinkler and microsprinkler due to favorable moisture content in root zone and better microclimatic conditions in crop canopy. Though, the total number of tubers per plant were maximum in drip, the lower proportion of large tubers resulted into reduced total tuber yield per hectare. The drip method of irrigation resulted into maximum number of medium size potato (50 to 100 gm) in terms of weight (38%) and in terms of number (36%) and surface method of irrigation resulted into maximum number of small size tubers (less than 50 gm) in terms of weight (22%) and in terms of number (37%) also. The results obtained are in line with reported earlier by Onder *et al.* (2005).

Table 3. Potato tuber size distribution under different irrigation methods and regimes

Treatment	Small size < 50 gm		Medium size 50-100 gm		Large size > 100 gm		Potato greening, %	
	% No.	% Wt.	% No.	% Wt.	% No.	% Wt.	% No	% Wt.
Irrigation systems								
Sprinkler	29.81	10.21	27.59	24.59	37.06	61.04	5.54	4.2
Micro-sprinkler	28.01	12.05	29.01	28.75	33.6	53.49	9.38	5.78
Drip	29.52	18.96	36.03	37.63	29.73	40.69	4.64	2.73
Surface	36.96	22.25	33.04	33.04	21.37	38.35	8.63	6.36
C.D. at 5 %	5.05	2.81	5.85	5.85	1.53	23.05	2.78	2.38
Irrigation regimes								
I_1	24.88	10.48	34.09	29.57	30.36	52.49	10.7	7.46
I_2	28.83	8.41	30.28	28.37	33.19	58.21	7.7	5.01
I_3	29.14	16.05	30.71	28.64	33.5	51.1	6.65	4.21
I_4	30.04	19.13	34.23	31.47	29.06	45.04	6.67	4.36
I_5	38.11	29.36	30.25	31.4	28.42	36.98	3.22	2.26
C.D. at 5%	11.28	6.85	19.10	18.55	4.65	6.44	2.37	1.88

Table 4. Water applied and WUE under different irrigation methods and regimes for the years 2012 to 2014 (Average of three years)

Treatments	Potato tuber yield, t/ha	Total water applied, cm	WUE q/ha-cm	Water saving, %	Increase/ decrease in yield, %
A. Irrigation systems					
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	-	—
C.D. at 5 %	2.17				
B. Irrigation regimes					
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**
C.D. at 5%	2.71				

* Increase in yield over surface
** Decrease in yield over I_2
*** Water saving over I_1

Table 3 shows that irrigation scheduled at I_1 and I_2 did not differ the small, medium and large size potato significantly. Higher number of large size tubers at irrigation regime I_2 was recorded whereas; corresponding higher values of medium and small size tubers were recorded in I_1. On the other hand, when irrigation was scheduled at I_5, large size tuber reduced significantly because of increase in number of smaller size tubers under moisture stress and vice versa. Kumar *et al.,* (2007) reported increase in tuber weight with increased irrigation water.

Green potatoes

The greening of potato is usually attributed to exposure of tubers to atmosphere. In general, 3 to 6 percent green tubers were found in different irrigation methods. Statistical significant difference in greening of potato was observed under different irrigation methods. The greening of potato was found to be more in sprinkler, micro-sprinkler and surface method of irrigation due to displacement of soil particles. The drip method of irrigation resulted into minimum greening of potato in terms of weight (2.7%). The greening of tubers was also found to be increased with increased levels of irrigation and found maximum 97.55 in terms of weight in regime no. I_1.

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 54 and 38 per cent increase in yield, respectively, without saving any water as compared to surface method of irrigation (Table 4). Whereas, drip method produced I_2 per cent more yield with 27 per cent water saving as compared to surface method. Among different irrigation systems, sprinkler system recorded higher WUE than microsprinkler, drip and furrow irrigation due to higher crop yield with less use of water. By and large, WUE is the function of crop yield and total water applied. Different irrigation regimes influenced irrigation water-use efficiency (WUE) of potato. There was an increase in WUE with decline in irrigation regimes. The maximum WUE in I_5 reveals less water expense under this irrigation regime but tuber yield was decreased upto 37 % as compared to I_2. However, interactions between irrigation system and scheduling were found non-significant. Islam *et al.,* (1990) also reported similar findings.

CONCLUSION

The advanced methods of irrigation viz., sprinkler, microsprinkler and drip produced 12 to 54 per cent higher potato tuber yields than surface method of irrigation. The sprinkler method of irrigation was found superior to other methods for potato in terms of increased productivity (21.87 t ha^{-1}) and higher WUE (7.70 q ha^{-1} cm^{-1}) amongst all irrigation systems under limited water supply.

Irrespective of irrigation methods, the irrigation regime with (1.2 IW/CPE ratio in sprinkler, microsprinkler and surface method and 1.10 wetted area factor under drip method resulted in highest tuber yield.

The potato tuber size was influenced with irrigation methods and irrigation regimes. The sprinkler and microsprinklers produced maximum number of large size tubers in terms of weight and numbers whereas more medium and small tubers were observed in drip and surface irrigation respectively.

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