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Influence of irrigation methods and fertilizer levels on productivity of potato (*Solanum tuberosum*)

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ABSTRACT

A experiment was laid in split-plot design and the treatments comprised sprinkler, drip and furrow irrigation as main plot along with three doses of fertilizers, viz F_1 (NPK @ 150:150:125 kg/ha), F_2 (NPK @ 125:125:100 kg/ha) and F_3 (NPK @ 100:100:75 kg/ha) as sub-plot treatments. Results of the study indicated that irrigation methods manipulated the hydrothermal regimes of the soil comprehensively and mean maximum monthly temperature was lowered by about 1.2°C under sprinkler irrigation. Under drip irrigation, moisture was near to the field capacity throughout the growth period, whereas, in conventional furrow irrigation, the moisture status curve traveled from above field capacity to 50% moisture depletion conditions. The yield of tubers was appreciably higher under sprinkler and drip, compared to furrow irrigation method. F_1 and F_2 exhibited non significant differences among themselves, in respect of tuber yield, but were significantly higher than F_3. Economic analysis indicated that sprinkler irrigation and F_2 resulted in optimum benefit: cost ratio.

Key words: Benefit : cost ratio, Drip, Field capacity, Hydrothermal regimes, Split-plot design, Sprinkler

Potato (*Solanum tuberosum* L.) ranks fourth among major food crops of the world, occupying an area of 19.26 million ha with annual production and productivity of 320.71 milliontonnes and 16.64 tonnes/ha, respectively (http://www.fao.org). Asia and Europe are the world's major potato producing regions, accounting for more than 80% of world production. India ranks third with an annual production of 26.28 million tonnes.

Irrigation and fertilization are two important inputs in potato production and increased production depends upon efficient use of irrigation water and fertilizers throughout the growth period. In the present day context, the effective and economic utilization of water and fertilizers is very essential to reduce the cost of cultivation and can best be achieved through the use of improved irrigation techniques, viz drip and sprinkler and supplying balanced and adequate doses of fertilizers. Use of drip and sprinkler irrigation can increase the yield up to 20–40% along with water saving up to 39% in potato crop (Pawar *et al*. 2002). However, their adoption is restricted mainly due to huge investment needed for installation during the initial period. Therefore, the economic feasibility of these techniques is needed to be assessed for a short-duration crop like potato. The response of applied fertilizers is also expected to vary with different methods of irrigation as frequency of water application is different in sprinkler, drip and conventional furrow irrigation system. Further, it has been reported that soil temperature causes large fluctuations in potato yield and can be manipulated to some degree by adjusting the soil moisture. Therefore, the present studies were conducted to evaluate variable fertilizer doses under different irrigation methods and assess the economic feasibility of these techniques.

MATERIALS AND METHODS

The studies were carried out at the Experimental Farm, Department of Soil Science and Water Management, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Himachal Pradesh. The farm is located at an elevation of 1 150 m above mean sea level and lies at 30°50'30" N latitude and 77°08'30"E longitude. Field trials were conducted on potato cv. Kufri Jyoti during spring season (February to May) of 2006 and 2007. The soils were Typic Entrocrept at subgroup level as per Soil Taxonomy of USDA and exhibited nearly neutral reaction, low salt concentration, medium organic carbon, available phosphorus and potassium and low available nitrogen status (Table 1).

The experiments were laid out in split-plot design with three main plot and three sub-plot treatments replicated four times as per details given below:

Main plot treatments (irrigation methods) = 3

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Table 1 Characteristics of the soil before the start of the experiment

Soil characteristic	Contents
*p*H	6.80
Electrical conductivity (dS/m)	0.25
Organic carbon(g/kg)	8.10
Available N(kg/ha)	226.33
Available P(kg/ha)	36.10
Available K(kg/ha)	230.55

I_d, Drip irrigation; I_s, sprinkler irrigation; I_f, furrow irrigation

Sub-plot treatments (fertilizer doses) = 3

F_1, NPK @ 150:150:125 kg/ha; F_2, NPK @ 125:125:100 kg/ha; F_3, NPK @ 100:100:75 kg/ha

Replications = 4

Sprinkler irrigation was scheduled at IW/CPE = 1.2 when CPE was 3.0 cm. The amount of water to be applied through drip irrigation was calculated employing following formula:

$$V = Ep \times Kc \times Kp \times A \times N - (Re \times A)$$

Where,

V, volume of water (litres); A, area of the plot; Ep, average daily pan evaporation (last 15 years); N, number of days in the month; Kc, crop factor; Kp, pan factor; Re, Effective rainfall

The amount of water calculated for the whole month, was applied at alternate days. Furrow irrigation was scheduled at an interval of 10 days and 5 cm of water was applied at each irrigation.

At the end of experiment, soil samples were drawn from each plot to access the nutrient status under different treatments. Soil temperature and moisture were constantly monitored throughout the experiment period and were recorded bi-weekly. The yield of tubers/plot was recorded at the end of the experiment and expressed into metric tonnes/ ha (mt/ha). The results obtained during two years were pooled and data thus obtained were subjected to statistical analysis as per methods outlined by Gomez and Gomez (1984). After taking into consideration the variable and fixed inputs, the expenditure incurred on various inputs was worked out for each treatment. The selling price of potato was ₹ 8 000/ tonnes and gross returns were calculated on the basis of this price. Benefit-cost ratio was worked out for different treatments. At the end of the experiment, total amount of water applied was calculated for each irrigation treatment and the water use efficiency (tonnes/ha cm) was calculated as per the formula:

$$\text{Water-use efficiency} = \text{Total yield of tubers (tonnes)} / \text{total water applied (cm)}$$

RESULTS AND DISCUSSION

Moisture status in each of the irrigation treatments (Figs 1, 2) depicts that the soil moisture was nearly at field capacity throughout the growth period in the drip irrigation at 7.3 and 12 cm depths. In sprinkler irrigation, 20–25 % deflection of moisture status curve from field capacity line was observed, whereas in the conventional furrow irrigation, the moisture status curve traveled from above field capacity to 50 % moisture depletion condition. This may be due to the fact that water was applied frequently in lower amounts in drip and sprinkler irrigation as compared to heavy application under furrow irrigation. It resulted in water stress to the crop and also temporarily decreases aeration in the soil which is very detrimental for a sensitive crop like potato. Pawar *et al.* (2002) have also reported similar findings and attributed higher yields obtained under sprinkler and drip irrigation to better availability of moisture throughout the growth period in these advanced methods of irrigation.

Data on mean monthly temperature at 10 and 20 cm soil depths presented in Figs 3, 4 show that sprinkler irrigation

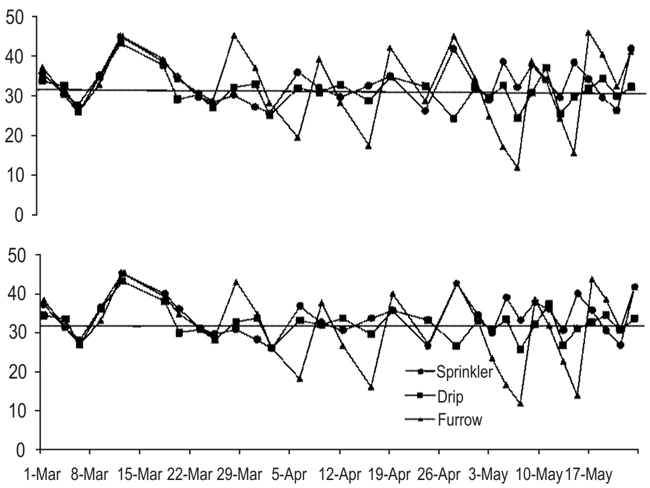

Fig 1 Volumetric water content (θ) under different irrigation methods during 2006

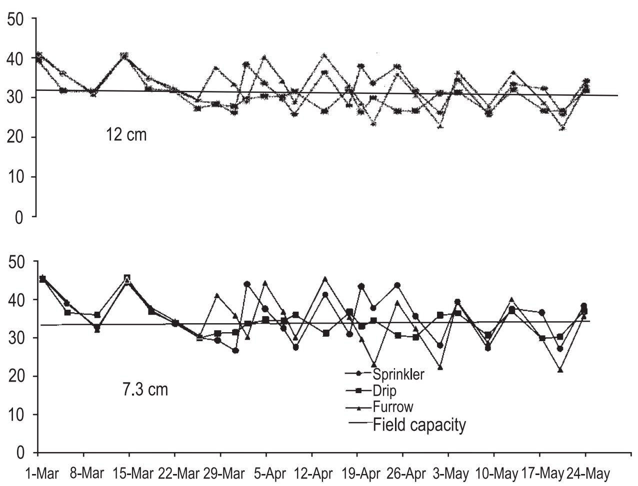

Fig 2 Volumetric water content (θ) under different irrigation methods during 2007

lowered the mean maximum monthly temperature by about 1.2°C as compared to drip and furrow irrigation method. It might be due to evaporative cooling caused by water sprinkled over the plants, better moisture status and thus higher heat capacity of the soil. Kohl (1973) has also reported that irrigating the potatoes through sprinklers at 5–7 days interval might reduce the soil temperature by 1–2°C during warm weather and less during a cooler period.

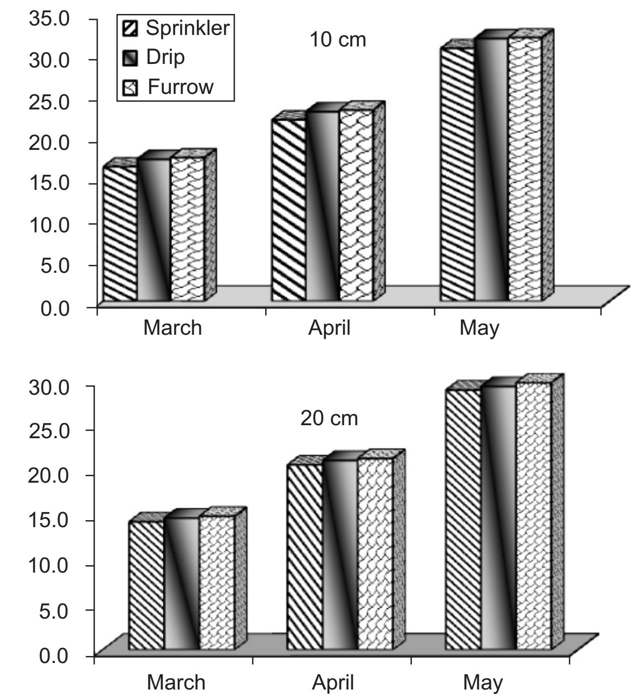

Fig. 3 Mean monthly maximum temperature at 10 and 20 soil depths under different irrigation methods during 2006

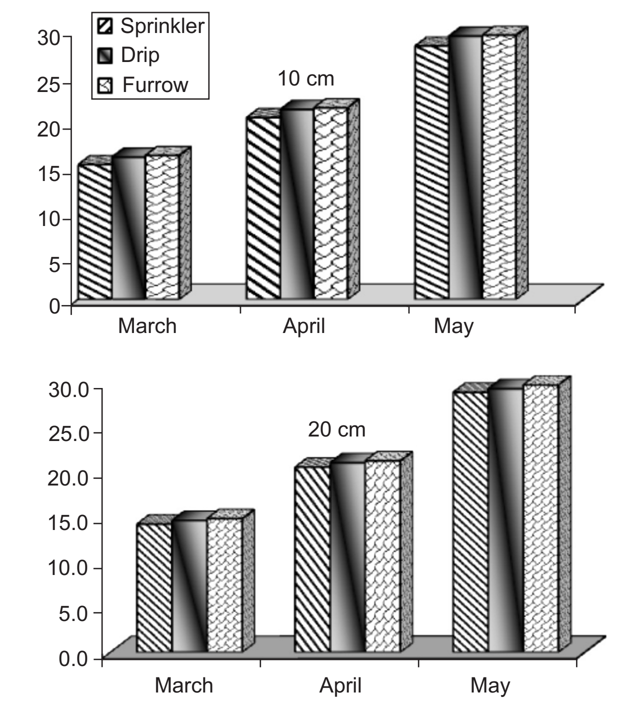

Fig 4 Mean monthly maximum temperature at 10 and 20 soil depths under different irrigation methods during 2007

Similar findings were also reported by Grewal and Singh (1978), where during spring season, maximum and minimum temperature was lowered in low tension treatments.

A consistent and significant increase in available P and K status of soil was observed with successive increase in the doses of NPK fertilizers (Table 2).The effect of fertilizer combination treatments on available P and K status of the soil was remarkable and maximum content (67.57 and 275.33 kg/ha, respectively) was observed under F_1.

The increase in available P status of soil due to fertilizer application may be attributed to the fact that soluble phosphate fertilizers applied to the soil undergo changes into different reaction products. Crop removal accounts for only about 20% of the applied P and the rest remains in soils resulting

Table 2 Effect of irrigation methods and fertilizer doses on available nutrients

Available nutrient	Fertilizer doses (kg/ha)	Irrigation methods			
		Furrow	Drip	Sprinkler	Mean
Nitrogen	F_1 NPK@ 150:150:100	224.22	243.82	240.69	236.25
	F_2 NPK@ 125:125:75	219.52	236.77	234.42	230.23
	F_3 NPK@ 100:100: 50	210.90	232.85	229.71	224.49
	Mean	218.21	237.81	234.94	
Phosphorus	F_1 NPK@ 150 150 125	65.52	68.88	68.32	67.57
	F_2 NPK@ 125 125 100	58.80	63.28	63.28	61.79
	F_3 NPK@ 100 100 75	54.88	56.56	56.00	55.81
	Mean	59.73	62.91	62.53	
Potassium	F_1 NPK@ 150 150 125	271.60	278.60	275.80	275.33
	F_2 NPK@ 125 125 100	254.80	266.00	264.60	261.80
	F_3 NPK@ 100 100 75	240.80	252.00	250.60	247.80
	Mean	255.73	265.53	263.67	

CD (p = 0.05)

Available N	Available P	Available K
Irrigation methods = NS	Irrigation methods = NS	Irrigation methods = NS
Fertilizer doses = NS	Fertilizer doses = 5.28	Fertilizer doses =13.89
I X F = NS	I X F = NS	I X F = NS

into build-up of phosphorus as residual P. Potassium is a mobile element and soil solution K is either fixed in clay lattice or on exchange sites. Higher rates of application has higher fixation and thus results in build-up of potassium in the soil. Similar findings were also reported by Bhalerao *et al*. (2001).

Data presented in Table 3 depicts that method of irrigation and fertilizer doses produced remarkable effects on the yield of potato. Sprinkler and drip irrigations produced about 15% (24.51 mt/ha) and 12% (24.0 mt/ ha) higher yield as compared to furrow method (21.41 mt/ha) of water application, however, differences between drip and sprinkler methods were non-significant. Higher tuber yield under sprinkler and drip irrigation could be attributed to optimum soil moisture throughout the period of crop growth which resulted in manipulation of soil temperature and helped in better root growth and tuber development. Pawar *et al.* (2002) have also reported that sprinkler and drip irrigation system produced in significantly higher potato yield compared to conventional surface irrigation method. They also concluded that the moisture availability might be the prime factor responsible for enhancement of production potential of potato in advanced irrigation methods like sprinkler and drip. Ahire *et al*. (2000) and Saggu and Kaushal (1992) have also reported similar findings.

Application of N, P and K in different combinations brought significant variation in the tuber yield. There was increase in tuber yield with increasing doses of fertilizers, however, increase was significant only up to F_2 (NPK @ 125:125:100 kg/ha). The increase in yield might be due to the higher availability of nutrients. Datt *et al.* (2002) in their studies on sprinkler irrigated potato in Lahaul valley of Himachal Pradesh have also reported that application of NPK (100+100+50 kg/ha) increased the tuber yield by 156% over control. Gayathri *et al.* (2007) have also reported that the response of potato to fertilizer nutrients increased with increased levels and attributed the increased uptake to higher availability of nutrients and increased absorptive area resulting in higher tuber yield.

Economic analysis revealed that benefit : cost ratio increased with the use of sprinkler as compared to drip and furrow irrigation, when equal doses of fertilizers were applied (Table 4). This might be due to the fact that tuber yield was

Table 3 Yield of tubers (million/ha) under different irrigation methods and fertilizer levels

Fertilizer doses(kg/ha)	Irrigation methods			
	Furrow	Drip	Sprinkler	Mean
F_1 NPK@ 150:150:125	22.46	24.91	25.60	24.39
F_2 NPK@ 125:125:100	22.03	24.82	25.12	23.99
F_3 NPK@ 100:100:75	19.74	22.28	22.82	21.62
Mean	21.41	24.00	24.51	

$CD_{0.05}$ irrigation methods = 1.57 fertilizer doses = 1.17 I × F = NS

Table 4 Economics under different methods of irrigation and fertilizer doses

		Drip		Sprinkler		Furrow
Cost of cultivation (₹)	F_1	118 800	F_1	113 850	F_1	107 150
	F_2	117 130	F_2	112 180	F_2	105 480
	F_3	115 460	F_3	110 510	F_3	103 810
Net returns (₹)						
	F_1	80 480	F_1	90 950	F_1	72 530
	F_2	81 430	F_2	88 780	F_2	70 760
	F_3	62 780	F_3	72 050	F_3	54 110
Benefit : cost ratio						
	F_1	0.68	F_1	0.80	F_1	0.68
	F_2	0.70	F_2	0.79	F_2	0.67
	F_3	0.54	F_3	0.65	F_3	0.52

significantly higher under sprinkler irrigation and also low cost of installation of the system. Pawar *et al*. (2002) have also reported that sprinkler method of irrigation was economically beneficial for potato crop. In spite of 25% water saving over furrow method, drip irrigation was found less economical for potato crop due to very high initial investment and lower yield compared with sprinkler irrigation. Amongst the fertilizer doses, F_1 and F_2 resulted in almost equal returns which were higher than F_3 fertilizer combination treatment suggesting F_2 (NPK @ 125 125 100 kg/ha) as the optimum dose.

Water-use efficiency was higher under drip and sprinkler irrigation, whereas furrow irrigation exhibited lowest water use efficiency suggesting that drip and sprinkler systems of irrigation provide scope to utilize water resources effectively and efficiently and also enhance crop productivity. It may be noted that among all the irrigation methods, F_1 and F_2 doses of fertilizers exhibited higher values of water use efficiency as compared to F_3 indicating that water use efficiency can be increased by using correct and adequate fertilizer doses.

It can be concluded that methods of irrigation comprehensively manipulated the hydro-thermal regimes of

Table 5 Water-use efficiency (tonnes/ha cm) under different irrigation methods and fertilizer levels during 2006–07

Fertilizer doses(kg/ha)	Furrow	Drip	Micro-sprinkler
2006			
F_1 NPK@ 150;150:125	0.56	0.88	0.89
F_2 NPK@ 125:125:100	0.55	0.88	0.87
F_3 NPK@ 100:100:75	0.49	0.79	0.79
Mean	0.54	0.85	0.85
2007			
F_1 NPK@ 150:150:125	0.59	0.82	0.73
F_2 NPK@ 125:125:100	0.57	0.81	0.72
F_3 NPK@ 100:100:75	0.50	0.73	0.65
Mean	0.53	0.77	0.68

the soil. The soil moisture was nearly at field capacity in drip and sprinkler irrigation, whereas, in furrow irrigation it indicated that the crop is exposed to temporary water stress which may be detrimental for a sensitive crop like potato. Mean maximum temperature was observed to be lower under sprinkler irrigation, whereas furrow irrigation recorded the highest. Sprinkler irrigation also registered highest yield of tubers. It may be further concluded that use of sprinkler irrigation along with application of NPK @ 125 125 100 kg/ ha gives optimum yield and hence results in maximum benefit: cost ratio and water-use efficiency.

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