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Microsprinkler, drip and furrow irrigation for potato (*Solanum tuberosum*) cultivation in a semi-arid environment

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ABSTRACT

A study was conducted during 2003–04 to compare microsprinkler, drip and furrow irrigation systems for potato (*Solanum tuberosum* L.) production at Central Institute of Post Harvest Engineering and Technology, Abohar, Punjab. Each irrigation method was combined with 4 irrigation levels, ie IW:CPE ratio of 1.20, 1.00, 0.80 and 0.60. Better crop performance was recorded under microsprinkler regime. The highest potato yield (31.60 tonnes/ha) was obtained with microsprinkler, followed by drip (29.83 tonnes/ha) and furrow (22.6 tonnes/ha) irrigation systems when irrigation was scheduled at 1.20 IW:CPE. Irrespective of irrigation system, potato tuber yield increased with increasing irrigation level from 0.60 to 1.20 IW:CPE. However, highest water- use efficiency (1.37 q/ha-mm) was recorded with 0.80 IW:CPE under microsprinkler irrigation. Water application of 257 and 261 mm was found optimal for attaining the maximum yield under microsprinkler and drip irrigation systems respectively. Fertilizer-use efficiency was highest (71 kg/kg) in microsprinkler, followed by drip (67 kg/kg) and furrow irrigation (48 kg/kg). Economic analysis revealed that using microirrigation for potato production in semi-arid environment is a profitable alternative of existing irrigation method.

Key word: Drip, Economics, Furrow irrigation, Irrigation scheduling, Microsprinkler, Potato yield

The south-west part of Punjab falls under semi-arid region and known for cotton-growing belt owing to well developed canal irrigation network. Agriculture of this region is completely dependent on canal water supply because groundwater is saline. In last few years, decline in water availability and irregular canal water supply associated with various pest problems caused reduction in cotton yield and subsequently farm income. Farmers are bound to shift to some other remunerative crops. Vegetable may be a good option but it requires frequent and ensured water supply because they are considered very sensitive to soil moisture stress (Jeffries and Meckerrm 1993). Potato cultivation would be a possible alternate to increase the farm income, if efficient and reliable irrigation management strategies are adopted to maintain optimum moisture in the effective root zone. It can be achieved best with the use of modern irrigation system coupled with suitable irrigation scheduling under limited water resources, particularly in semi-arid region. In this region, storage structure is needed to ensure regular water supply for microirrigation system because, due to one and other reasons canal water supply is not regular and ground water quality is not fit for irrigation. Though, drip irrigation has proven its potential to increase yield and water productivity but the climatic conditions of this region seems more suitable to microsprinkler because microsprinkler protects crops from adverse climatic conditions, which helps in better growth and yield (Spieler 1994).

Superiority of drip irrigation or sprinkler irrigation over traditional irrigation methods in terms of yield and economics is now well established fact (Narayanamoorthi 1997, Pawar *et al.* 2002). But economic viability of microsprinkler or drip irrigation system for potato cultivation in those areas where surface water is stored for using microirrigation systems is yet to be answered. It creates doubt that whether agriculture with microirrigation would be economically viable or not because an additional investment is required for water storage tank apart from the irrigation system cost. It is, therefore, imperative to evolve efficient, economical and reliable irrigation management strategies for successful early potato cultivation and to increase productivity and profitability of existing bio-production system for canal irrigated area of semi-arid environment. Keeping these facts in view, the study was planned to evaluate the response of potato crop to drip, microsprinkler and furrow (traditional) irrigation systems and

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to answer whether potato production with microirrigation in canal irrigated areas is economically viable.

MATERIALS AND METHODS

A field study was conducted at the research farm of Central Institute of Post Harvest Engineering and Technology, Abohar, Punjab (30°, 09' N, 74°, 13' E and altitude of 186 m above msl), during October–December 2003 and 2004. The climate of experimental site was semi-arid with extremely hot summers and cold winters. The soil was sandy loam with *p*H 8.28. The soil moisture content in 0–45 cm soil layer was 12.50 and 3.90% (w/w) at field capacity (–0.03 MPa) and wilting point (–1.5 MPa), respectively. The initial bulk density of soil for 0–45 cm depth was 1.55 g/cc. Potato *cv.* 'Kufri Chandramukhi' was grown with microsprinkler, drip and furrow irrigation systems. Each irrigation system had 4 irrigation levels, viz 1.20 IW/CPE, 1.00 IW/CPE, 0.80 IW/CPE and 0.60 IW/CPE. Class-A open pan evaporimeter was located at a site adjacent to the experimental area with moderate grass cover to estimate the pan evaporation. Irrigations were scheduled at the previous day pan evaporation data. Micro-jet type microsprinklers (discharge 64.8 lph) and drip-in type drip irrigation systems were used to irrigate the experimental crop. The spacing between 2 microsprinklers was 3 m while stake height of microsprinkler was 45 cm. Drip lateral was placed on each row of potato and spacing between 2 drippers was 0.45 m. The area of each experimental plot was 36 m^2 (6 m×6 m). A buffer zone spacing of 1.0 m was provided between the plots. Recommended dose of nutrients, i e 187:62.5:125 kg/ha of N:P:K was applied as per schedule during crop raising (Anonymous 2001). In microsprinkler and drip irrigation systems, nutrients were applied as fertigation, while in furrow irrigation system, broadcasting was done. Soluble fertilizers, viz. polyfeed (grade 19:19:19 of NPK) and Multi K (0:0:48) along with urea were used for applying the required nutrient to the crop. Crop was harvested after 12 weeks of planting to estimate fresh tuber yield. Irrigation water-use efficiency and fertilizer-use efficiency were computed by following standard procedure. Total nutrient (N:P:K) applied was used in estimation of fertilizer-use efficiency of potato.

To assess economic viability of different irrigation systems for potato production in canal irrigated areas, both fixed and operating costs were taken into consideration. Economics of potato production under variable irrigation were calculated with the assumption that salvage value of the different components of irrigation systems will be zero after their useful life. Useful life of motor and sand filter, water storage tank and other irrigation system components was assumed 15, 20 and 8 years respectively for economic analysis. The annual fixed cost for water development and irrigation systems was calculated using the approach of James and Lee (1971). Net returns were estimated as difference between gross income and total production cost. Gross returns were product of yield and wholesale market price of potato.

The experiment was laid out in split-plot design (SPD) with irrigation systems in main plots and levels in sub-plots with 3 replications. The data were analyzed statistically by standard analysis of variance (ANOVA). Least significant difference (LSD) test was used to determine whether differences exist between certain comparisons. The probability level for determination of significance was 0.05.

RESULTS AND DISCUSSION

Fresh potato tuber yield

Comparison of irrigation treatments showed a consistent increase in potato tuber yield with increasing irrigation from 0.60 to 1.20 IW/CPE (Table 1). Yield increased from 13.53 tonnes/ha under 0.60 IW/CPE irrigation schedule in furrow irrigation to a maximum of 31.60 tonnes/ha in microsprinkler irrigation system with irrigation scheduling of 1.20 IW/CPE. The lowest tuber yield recorded at 0.60 IW/CPE under furrow irrigation regime might be due to water stress experienced by the crop. The reduction in tuber yield was recorded due to reduction in mean tuber weight under water stress condition. Yaun *et al.* (2003) reported decrease in tuber

Table 1 Potato yield and irrigation water-use efficiency (IWUE) as influenced by variable irrigation under different irrigation systems

Treatment	Potato yield (tonnes/ha)			Mean	IWUE (kg/ha- mm)			Mean
	Irrigation system (IS)				Irrigation systems			
	Microsprinkler	Drip	Surface		Microsprinkler	Drip	Surface	
Irrigation (I) at								
1.20 IW/CPE	31.60	29.83	22.60	28.09	130	121	081	1.11
1.00 IW/CPE	29.37	27.18	19.90	25.48	137	128	082	1.16
0.80 IW/CPE	26.18	24.65	17.05	22.63	136	131	081	1.16
0.60 IW/CPE	20.02	19.30	13.53	17.62	119	122	079	1.07
Mean	26.79	25.54	18.27		131	126	081	
LSD (*P*=0.05)	Irrigation system (IS)		= 1.98		Irrigation treatment (IS)		= 0.09	
	Irrigation treatment (I)		= 1.57		Irrigation system (I)		= Ns	
	IS×I		= Ns		IS×I		= Ns	

weight with decreased irrigation water. Kashyap and Panda (2002) also observed significantly higher potato yield under high frequency irrigation. Difference in tuber yield obtained under microsprinkler and drip irrigation systems was statistically non-significant, but significantly higher than furrow irrigation method. The higher yield in microsprinkler and drip irrigation systems might be due to the fact that frequent watering resulted into higher water potential, thus minimizing fluctuation in soil moisture in effective root zone, which holds promise for increase in crop yield (Hanson *et al.* 1997). However, irrigation systems and irrigation scheduling interaction effects on potato yield was found non-significant. Micro sprinkler and drip irrigated crop registered 31.80% and 28.46% higher yield (mean of 2 years) over furrow irrigation. The better crop performance under microsprinkler could be attributed to minimum influence of frost, white fly and nutrient leaching. It was observed (visual observation) that whitefly attack was not so severe under microsprinkler regime as compared to drip and furrow irrigated crop. Frequent irrigation with microsprinkler washed the leaf canopy and minimized the whitefly infestation. Apart from this, microsprinkler irrigation might have created better microclimate, which facilitated better photosynthesis, root aeration and plant growth which resulted into higher yield. Findings are in accordance with Holzapfel *et al.* (2000) who reported better soil aeration in root zone of Kiwi crop under microsprinkler irrigation as compared to drip irrigation system, and recorded higher yield. Further, during tuberization (in December) minimum temperature was as low as 5–12 °C for few days. Microsprinkler irrigation system might have protected the crop from adverse effect of low temperature by sprinkling water droplets on the leaves of the plant, helped in better growth, early maturity (one week early) and higher potato yield as compared to traditional method. Spieler (1994) also reported that microsprinkler protects crops from adverse climatic conditions which help in better growth and development of plant.

Total water applied and water-use efficiency

Different irrigation levels influenced irrigation water-use efficiency (IWUE) of potato. Table 1 shows an increase in IWUE up to 0.80–100 IW/CPE and thereafter tended to decline. The maximum IWUE in 0.80–1.00 IW/CPE reveals that potato yield was highest with less water expense under this irrigation regime. Kumar *et al.* (2007) also observed variation in water-use efficiency with variable irrigation for onion. By and large, IWUE is the function of crop yield and total water applied. Thus, IWUE decreased with increasing quantity of water. Among different irrigation systems, microsprinkler system recorded higher IWUE than drip and furrow irrigation due to higher crop yield with less expense of water.

Fertilizer-use efficiency

Microirrigation systems had significant effect on fertilizer use-efficiency of potato (Table 2). Fertilizer-use efficiency was significantly higher in microsprinkler and drip irrigation system than furrow irrigated crop because of considerable increase in yield with the same amount of irrigation and nutrient. Rumpel (2003) reported higher nutrient availability to the crop in fertigation as compared to broadcast application of fertilizer, which may lead to higher potato production with microirrigation systems. Fertilizer use efficiency was highest in case of microsprinkler. Our study also revealed increase in fertilizer-use efficiency with increasing irrigation levels. However, interactions between irrigation system and scheduling were found non-significant.

Table 2. Fertilizer-use efficiency (kg/kg) of potato at different irrigation treatments under different irrigation systems

Treatment	Irrigation system			Mean
	Microsprinkler	Drip	Surface	
1.20 IW/CPE	84.0	80.0	60.0	75.0
1.00 IW/CPE	78.0	72.0	51.0	67.0
0.80 IW/CPE	70.0	66.0	46.0	60.0
0.60 IW/CPE	53.0	51.0	36.0	47.0
Mean	71.0	67.0	48.0	

LSD (P=0.05), Irrigation system (IS) = 5.0Irrigation treatment (I) = 4.0 IS×I = Ns

Yield response to irrigation water

To establish yield response of potato to irrigation water applied, yield obtained from the field study was plotted as a function of irrigation water applied (Fig 1). The developed empirical relationships presented in Fig 1 show quadratic response for potato yield to irrigation water applied under each irrigation system. This was might be due to poor soil aeration and nutrient leaching caused by excessive soil

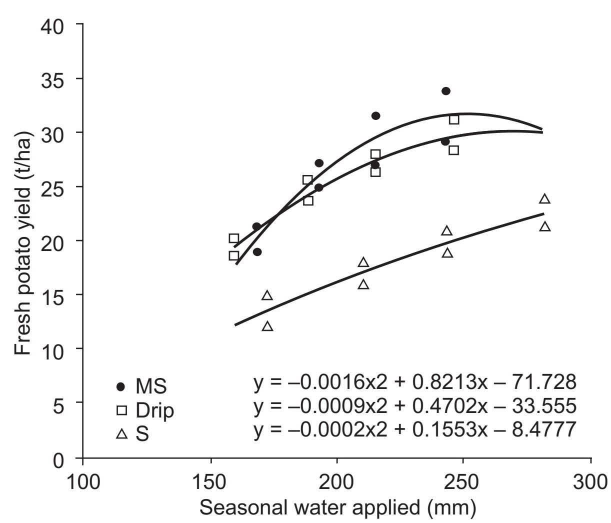

Fig 1 Response of tuber yield to irrigation water applied under different irrigation systems

moisture (Imtiyaz *et al.* 2000). Standard error for developed mathematical relationship was found to be 2.39, 1.44 and 1.40 tonnes/ha, to predict potato yield as the function of seasonal water applied under microsprinkler, drip and surface irrigation regime respectively. The co-efficient of determination 'R^2' was recorded to be 0.85, 0.94 and 0.89 for microsprinkler, drip and surface irrigation systems respectively. It can be concluded that across the range of irrigation water applied, microsprinkler and drip irrigated potato yield showed increase up to 257 and 261 mm of irrigation water and thereafter tended to decline. The decline beyond 257 and 261 mm in microsprinkler and drip irrigation system revealed that increase in yield was not in proportion to increase water supply. Hence, it is not advisable to apply water beyond above said values in respective irrigation system. Higher application of water may lead to non-ET uses like deep percolation and excess soil moisture. Efficient and economical management of precious water is prime concern for farmers and planners. However, almost linear effects of irrigation water on potato yield across the range of irrigation water applied was observed under furrow irrigation regime, which indicates potato crop required more irrigation (i e frequent watering than employed) to attain the maximum yield. Result of the study indicates that microirrigation produced higher yield and saved considerable amount of water than the present furrow irrigation practices. Higher yield in microirrigation (microsprinkler and drip) may be due to the fact that microirrigation systems enhance the nutrient availability by providing nutrient as fertigation (Hartz and Hochmuth 1996), whereas in furrow irrigation, fertilizer is applied as basal dose and split dose, which is always vulnerable to leaching. As a result crop suffers often from inadequate supply of N and sometime P.

Economic evaluation

Our results indicated that across this range of irrigation scheduling (0.60–1.20 IW/CPE), net returns from potato cultivation with existing furrow irrigation method varied from Rs 10 150 to 45 933/ha with different irrigation levels, whereas microsprinkler resulted significantly higher net returns with the same irrigation level due to higher productivity (Table 3). However, drip irrigation did not improve net returns instead of higher gross returns than furrow irrigation because of higher initial investment involved in installation of the system. Hence, it can be concluded that microsprinkler is the most appropriate irrigation system to maximize the profit per unit cropped area using limited available water in canal irrigated semi-arid environment. In this study, furrow irrigation also had ensured water supply from storage tank, but in actual condition, there is uncertainty in canal water availability, which may further lead to water stress and yield reduction. Hence, comparative economics may be even better in favour of microsprinkler. Study also revealed that irrigation levels had significant effect on returns from potato production. Similar trend was observed for all irrigation systems. Variation in profit with irrigation levels was due to the variation in yield (Kumar *et al.* 2006).

Table 3 Net returns (Rs/ha) of potato at different irrigation treatments under different irrigation systems

Treatment	Irrigation system			Mean
	Microsprinkler	Drip	Surface	
1.20 IW/CPE	54 881	40 580	45 932	47 131
1.00 IW/CPE	49 912	35 204	35 507	40 208
0.80 IW/CPE	37 936	28 695	23 401	30 010
0.60 IW/CPE	18 707	5 553	10 150	11 470
Mean	40 359	27 508	28 747	

The study indicated highest yield of early potato with 1.20 IW/CPE of irrigation under each irrigation system. But, microsprinkler recorded higher yield, irrigation production efficiency and fertilizer-use efficiency amongst all irrigation systems under limited water supply. Economics revealed that microsprinkler to be a good substitute for existing irrigation system for potato production in canal irrigated area of semi-arid climate.

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