



## SOIL & CROP SCIENCES | RESEARCH ARTICLE

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*Cogent Food & Agriculture* (2017), 3: 1369345



Received: 08 February 2017  
Accepted: 16 August 2017  
First Published: 25 August 2017

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Reviewing editor:  
Manuel Tejada Moral, University of  
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# Comparative effects of saline water on yield and quality of potato under drip and furrow irrigation

Gaurav Jha<sup>1\*</sup>, O.P. Choudhary<sup>2</sup> and Rakesh Sharda<sup>3</sup>

**Abstract:** A field experiment was conducted at the Research Farm of the Precision Farming Development Centre, PAU, Ludhiana in the Rabi season of the year 2015–2016. The potato variety Kufri Pukhraj, was sown by following drip and furrow methods of irrigation. Five irrigation treatments with good quality water (electrical conductivity, EC-0) and four with saline water treatments of 2,000 mmho/cm (EC-2), 4,000 mmho/cm (EC-4), 6,000 mmho/cm (EC-6) and 8,000 mmho/cm (EC-8) under split plot design along with three replications was followed. The results revealed that, plant height decreased with increasing salinity. Nevertheless, plant height under drip irrigation was greater than plant height under furrow irrigation at all levels of salinity. Number of tubers per plant, weight of tubers and tuber yield decreased with increasing salinity of irrigation water. However, the values of these parameters were more under drip irrigation than furrow irrigation and effects were pronounced at higher level of water salinities. Regarding tuber quality, there was a significant decrease in dry matter and starch content and increase in sugar content with increasing salinity of irrigation water. These quality parameters were observed to be better under drip irrigation over furrow irrigation method. Number of Grade A and B tubers were found to be higher in drip irrigation at levels of water salinity. On the contrary, Grade D tubers were predominant under furrow irrigation. It is concluded that, drip

### ABOUT THE AUTHOR



Gaurav Jha

Gaurav Jha is currently a doctoral candidate at New Mexico State University, and his research focuses on long-term monitoring of contaminations in soils, sediments, water and plants caused by the Gold King Mine spill using X-Ray Fluorescence spectrometry. His research interests is monitoring and remediation of contaminated and problem soils for agriculture. Gaurav pursued an MS in soil science as a Junior Research Fellow of Indian Council of Agricultural Research (ICAR) from Punjab Agricultural University. He received a BS in agriculture from Visva-Bharti University, Santiniketan, India. There, he served as a youth ambassador for Liberal Youth Forum and Chair for Alexis Centre for Agriculture and Rural Development, the youth organization of Visva-Bharti University, focusing mainly on helping farmers to obtain the best quality of seeds and management of crop fields. He also helped a tribal school in a village with creative learning and exposure to the society.

### PUBLIC INTEREST STATEMENT

The poor quality of water in arid regions is a major concern mainly due to dissolution of salts in groundwater used for irrigation purposes. It is important to manage the salts that accumulates at the root zone affecting the quality of fruits and vegetables in the farmers' fields. The objective of this study was to remove the accumulating salts away from the roots and observe its effect on potato tuber quality. Drip irrigation shows higher yield and better quality of fruits and vegetables than furrow irrigated fields. Installation of drip irrigation in potato field allows the tubers to grow in a wetting front formed in the soils drifting the salts away towards the periphery of this wetting front. It will be a promising practise in arid regions where salts reduce the crop quality due to osmotic effects.

irrigation is superior over furrow method producing higher tuber yield with better quality having more proportion of marketable tubers even at high salinity.

**Subjects: Agriculture; Environmental Sciences; Land Reclamation Pedology; Soil Conservation Technology**

**Keywords: drip irrigation; saline water; furrow irrigation; potato; tuber quality**

## 1. Introduction

In many countries, especially those in the arid climate zone with high rates of population growth, urbanization and industrialization, water is becoming a scarce natural resource. The increasing population will put an adverse impact on the fresh water allocation for irrigated agriculture in the years to come because of the competitive pressure. Due to this, low or marginal quality water will be used for irrigation in those areas where fresh water is becoming scarce. According to FAO (1995), under arid conditions, even with the availability of good water, irrigation projects lead to salinity problems (Gupta & Abrol, 1990). According to the study made by Katerji, van Hoorn, Hamdy, and Mastroilli (2003), there are two groups in which plants are classified. The first one consists of salt tolerant species, which maintain or improve their water use efficiency under salt stressed condition and the second one consists of the plants that are salt sensitive in which water use efficiency decline with increasing soil salinity. Based on this study, potato crop can be categorized under the first group. Furrow irrigation is a conventional practice for potato production in India. Patell, Prasher, Donnelly, and Bonnell (2001) reported the effect of initial soil salinity and irrigation water salinity on potato tuber yield and size in the field. They observed a decrease in these parameters with increasing salinity. Leaf water and osmotic potentials in potato declined significantly as salinity conditions intensified, with more accumulation of proline in the leaves (Heuer & Nadler, 1998). The negative effects of salinity on potato tuber formation are a consequence of the reduction in osmotic potential due to increasing salt levels in cells of tuber tissues which also leads to a reduction of water content and nutrient uptake in tubers (Momoh, Zhou, & Kristiansson, 2002). The reduction in yield can also be ascribed to structural deterioration and poor permeability of soils irrigated with poor quality saline water (Minhas & Gupta, 1992).

Drip irrigation has the potential to increase/sustain crop yields with less quantity of irrigation water. Drip irrigation, however, because of its costly installation is not widely used by the farmers in the country. However, in areas where salt content of groundwater is increasing progressively, drip irrigation is a better alternative, to obtain an optimized and higher yield along with better quality, over the conventional irrigation method (Hanson & May, 2011). Kang, Wang, Liu, and Yuan (2004), stated that the low rate and high frequent irrigation water through drip irrigation system, over a long period of time, can maintain high soil matric potential in root zone, compensating for the decrease of osmotic potential caused by the saline water irrigation, and constant high water potential can be maintained near the plant roots for the crop growth. Minhas (1996) regarded drip system as the most advantageous method for applying saline water to crops and also for maintaining well aerated conditions in the soil. According to Ragab (1998), drip irrigation offers the advantage of supplying water nearly on a daily basis, thereby keeping the water content of the soil and salinity of soil solution favourably at a stable level.

The potentials of drip irrigation have not yet been fully explored in India for the cultivation of vegetables. Since, little information is available about the yield and quality of tubers under drip irrigation using saline water, an evaluation of drip irrigation was necessary to confirm the crop response over the conventional irrigation method. This study aims to evaluate the comparative effect of drip and furrow irrigation on yield and quality of potato tubers using saline irrigation water treatments of four levels of salinity that had not been widely explored in the past. Enough literature is not available on quality parameters of the grade of potatoes as influenced by saline water applied through drip and furrow irrigation.

## 2. Materials and methods

The experiment was conducted at the Precision Farming Development Centre, Research cum Demonstration farm, Department of Soil & Water Engineering, PAU, Ludhiana (30°54' 34.26" N 75°48'

52.64° E) during Rabi season (mid-October 2015 to January 2016). Potato was planted in loamy sand soil with low organic matter content of 0.19 per cent, pH of 8.1 and an electrical conductivity of 1.7 dSm<sup>-1</sup>. The meteorological data was obtained from meteorological observatory of Punjab Agricultural University, Ludhiana during the crop season (October 2015 to January 2016). Mean maximum air temperature ranged between 13.1 and 28.0°C and the mean minimum temperature ranged between 14.8 and 5.0°C during the crop season.

The whole plot was divided into two parts—one for drip and other for furrow method. Each part had dimension of 15 m × 9 m having five saline water irrigation treatments. The dimension of each treatmental plot was 15 m × 1.8 m. Each treatment had three furrows and each furrow had a length of 15 m and 0.6 m. One crop line was sown on each ridge. The two methods of irrigation followed were drip and furrow irrigation. In case of drip irrigation, one lateral was provided on each ridge with dripper spacing of 30 cm. The variety used was Kufri Pukhraj, commonly used variety by farmers in the region. The five irrigation treatments were a good quality irrigation water and four different salinity levels of irrigation water as given below:

- i. Fresh water (control) at EC of 600–700 micromhos/cm (EC-0)
- ii. Water having EC of 2,000 micromhos/cm (EC-2)
- iii. Water having EC of 4,000 micromhos/cm (EC-4)
- iv. Water having EC of 6,000 micromhos/cm (EC-6)
- v. Water having EC of 8,000 micromhos/cm (EC-8)

Irrigation water in all salinity treatments was given at 100% ET<sub>c</sub> calculated on the basis of Penmen Monteith Method. The experiment was laid out in split-plot design. Each treatment was replicated thrice.

Pre-sowing irrigation was applied to the field to ensure adequate moisture in the soil profile at the time of planting. Twenty tonnes of well decomposed farmyard manure was incorporated in the cultivation area of 0.5 acres before sowing. The drip irrigation system was installed over the ridges in the experimental area on half of the field while the other half was prepared for furrow system of irrigation by making ridges. The main and sub-main lines were of 63 mm inside diameter PVC pipes and the laterals were of 16 mm diameter with 20 cm inline emitter spacing. The sowing was done by using 12 quintals of seed tubers per acre seeded manually after marking the plant to plant spacing of 20 cm. Crop was sown on 26 October 2015. The seed was treated with Emisan @ 2.5 g per litre of water for 10 min. A ridger was used for earthing up after 28 days after sowing (DAS). This was done to enhance proper tuberization. Manual weeding was done at 45 DAS and before dehauling. In case of furrow irrigated area, 75 kg of N (165 kg of urea), 25 kg of P<sub>2</sub>O<sub>5</sub> (155 kg of single superphosphate) and 25 kg of K<sub>2</sub>O (40 kg of muriate of potash) per acre was applied. All P and K, and half N was added at sowing and the remaining N at the time of earthing-up after 30 days of sowing. In case of drip irrigation of potato, the fertigation at the rate of 80 per cent fertilization of that in furrow was applied assuming drip to be more efficient system (Sharda, Siag, Kirandeep, Biwalkar, & Chawla, 2012). The first fertigation was started after germination by applying 24.5 kg urea, 6.6 kg mono ammonium phosphate and 6.7 kg muriate of potash (white) per acre was applied during first month of the growing period of the crop in 7 equal doses with 4 days interval. The remaining amount of fertilizer 97.5 kg urea, 26.2 kg mono ammonium phosphate and 26.7 kg muriate of potash (white) was applied during rest of the crop season (before last irrigation) in 13 equal doses with every second irrigation (4 days interval). Total rainfall during the growing season of crop was 41.5 mm and total evaporation (235.6 mm) recorded exceeded rainfall. Depending upon the rainfall received during the growth of crops, irrigation water applied was 256 mm under drip and 428 mm under furrow irrigation.

The data on plant height was recorded at 30, 60 and 75 days (at dehauling) after sowing. Weight of tubers, number of tubers per plant was obtained from five randomly selected tubers from each treatment and then averaged. Weight of tubers per plant was divided by number of tubers per plant

to obtain weight of individual tubers for each treatment. Tuber yield (tonnes per hectare) was recorded on treatment basis calculated on the basis of five plants sampled from drip and furrow irrigation rows, respectively. The quality parameters were assessed by determining total soluble solids (TSS) by hand refractometer by extracting a sap from a piece of sliced potato from a randomly selected tuber, starch and sugar content by Dubois method (DuBois, Gilles, Hamilton, Rebers, & Smith, 1956), dry matter content was determined by oven drying at 65 degrees Celsius for 48 h and weighing the samples for calculation of per cent dry matter and tubers were graded into four categories as per the weight (Grade A-more than 75 g, Grade B-50-75 g, Grade C-25-50 g and Grade D-less than 25 g.

### 3. Results and discussion

#### 3.1. Plant growth and yield attributes

##### 3.1.1. Plant height

Plant height is an index of growth and development of the plant over a period of time. The data recorded on plant height at 30, 60 and 75 days (at dehauling) after sowing are presented in the Table 1.

The data reveals that plant height continued to increase with the advancement in age of the crop under different irrigation treatments. At 30 days after sowing (DAS), plant height decreased with increase in the salinity of irrigation water. Mean plant height under good quality water was 24.03 cm. It was found to be statistically at par with EC-2 irrigation treatment but significantly better as compared to EC-4, EC-6 and EC-8 irrigation treatments. Plant height was more in drip irrigated plots than furrow irrigated ones. An average height attained by the plant at 30 DAS under drip irrigation was 20.7 cm while that attained by the plant under furrow irrigation averaged to 17.45 cm. Similarly, at 60 DAS and 75 DAS, height was observed to be decreasing with increase in salinity. Maximum mean height was recorded under good quality water while the minimum plant height was recorded at EC-8 irrigation treatment. The reason might be presence of salt in soil solution that decreases the osmotic potential of soil, creating water stress and making it difficult for the plant to absorb water necessary for growth and thus, plant height decreased with increasing salinity (Rimon, Goldberg, & Gornat, 1976). The data pertinent to height at 60 DAS reveals that plant height in drip and furrow under good quality irrigation water was at par. But as the salinity increased, differences between two methods were more pronounced. On an average, height attained by the plant under drip irrigation was 29.6 cm, while in furrow it was shorter (25.8 cm). At dehauling (75 DAS) the effects of salinity and methods of irrigation was similar to that observed at 60 DAS except that plant height increased further with ageing. Furthermore, the negative effect of salinity on height of the plant was more pronounced in case of furrow irrigation than drip irrigation. An average height attained by the plant under furrow irrigation was smaller about 20 per cent than that attained under drip irrigation

**Table 1. Effect of different saline water irrigation treatments on plant height (in cm) of potato tubers at 30 DAS, 60 DAS and at dehauling**

EC (dSm <sup>-1</sup> )	30 DAS			60 DAS			At dehauling		
	Irrigation method		Mean	Irrigation method		Mean	Irrigation method		Mean
	Drip	Furrow		Drip	Furrow		Drip	Furrow	
0	25.91	22.14	24.03	35.62	36.33	35.98	53.59	51.41	52.50
2	25.70	21.38	23.54	36.38	30.54	33.46	51.49	42.40	46.94
4	22.37	18.89	20.63	32.22	26.65	29.43	48.84	39.10	43.97
6	15.05	14.35	14.70	23.44	20.24	21.84	38.84	26.48	32.66
8	14.45	10.50	12.48	20.16	15.13	17.64	34.13	21.84	27.99
Mean	20.70	17.45		29.56	25.78		45.38	36.25	
LSD (5%)	EC = 2.27; IM = 1.81; EC × IM = NS			EC = 2.01; IM = 3.54; EC × IM = 2.84			EC = 3.38; IM = 2.70; EC × IM = 4.79		

method. In furrow irrigation the accumulation of salts near to the roots hinders the proper nutrient and water uptake, while in drip irrigation, a wetting bulb, also called as wetting front, builds up which removes the salt away from the root zone and accumulates at the periphery of the bulb formed due to water movement in soil moisture regime.

### 3.1.2. Weight of tubers per plant

The data regarding weight of tubers per plant presented in Table 2 depict a significantly lower average tuber weight under furrow irrigation (426.5 g) when compared with drip irrigation system (625.8 g). Mean tuber weight recorded under good quality irrigation water was significantly higher with a value of 725.2 g compared with different saline irrigation treatments. The mean tuber weight for salinity treatments varied from 633.2 g under EC-2 irrigation water treatment to as low as 341.8 gram under EC-8 irrigation treatment. The data recorded revealed that, maximum tuber weight per plant (815.3 g) was observed under good quality water irrigation treatment with drip system. The superiority of drip irrigation using saline water was established by the fact that at EC-4 treatment, tuber weight (620.0 g) was at par with that obtained under furrow plots irrigated with good quality water (635.0 g). Likewise, at the highest salinity of irrigation water (EC-8), drip irrigated potatoes weighed (390.3 g) similar to that obtained at EC-4 treatment under furrow irrigation (391.4 g). The minimum weight of tubers per plant (291.7 g) was observed with EC-6 irrigation water treatment under furrow irrigation.

The weight of tubers per plant between EC-8 and EC-6 irrigation treatment under furrow method. The weight of tubers per plant significantly reduced at higher salinity under furrow occurred due to the accumulation of salt around the proximity of root zone where tuber formation occurs. On the other hand, high tuber weight for each treatment under drip irrigation was achieved because of the distribution of salt due to water movement away from root zone. On an average, drip method of irrigation showed 31.8 per cent of higher weight of tubers per plant over furrow method.

### 3.1.3. Weight per tuber

Weight of individual tubers was significantly influenced by levels of salinity in water and methods of irrigation (Table 3). Mean tuber weight was significantly higher in case of drip irrigation (47.9 g) than furrow irrigation (36.7 g). With increase in level of salinity of irrigation water treatment mean tuber weight reduced from EC-0 to EC-8. Maximum tuber weight (50.6 g) was reported under good quality irrigation water in drip irrigated plots and it was at par with EC-2 treatment but further decreases at higher salinities were significant. However, individual tuber weight was significantly different for each irrigation water treatment when both the methods were compared. Individual tuber weight of drip irrigated plots at the highest salinity treatment (EC-8) was similar to that under furrow irrigation (42.3 g) at low salinity (EC-2).

**Table 2. Effect of different saline water irrigation treatments on the weight of tubers (in grams) per plant**

EC (dSm <sup>-1</sup> )	Irrigation method		Mean
	Drip	Furrow	
0	815.3	635.0	725.1
2	745.0	521.3	633.1
4	620.0	391.3	505.6
6	558.3	291.6	425.0
8	390.3	293.3	341.8
Mean	625.8	426.5	
LSD (5%)	EC = 34.1; IM = 53.9; EC × IM = 48.2		

**Table 3. Effect of different saline water irrigation treatments on the weight of individual tuber (in grams) for each treatment**

EC (dSm <sup>-1</sup> )	Irrigation method		Mean
	Drip	Furrow	
0	50.6	47.2	48.8
2	49.3	42.3	45.8
4	44.7	34.3	39.5
6	42.9	28.9	40.9
8	41.8	30.9	36.3
Mean	47.9	36.7	
LSD (5%)	EC = 5.4; IM = 2.7; EC × IM = 7.6		

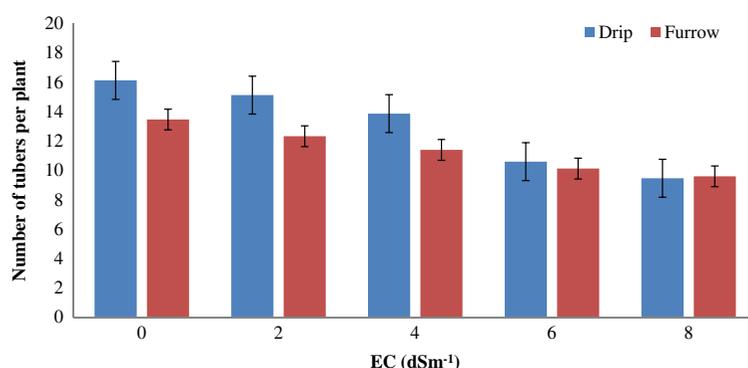
### 3.1.4. Number of tubers per plant

The number of tubers per plant along with tuber weight is an important index of the final yield of the crop. The data regarding number of tubers per plant is presented graphically in Figure 1. There was significantly higher mean number of tubers per plant under drip irrigation (13.0) than that under furrow irrigation method (11.4). When compared to furrow irrigation, number of tubers per plant was 16.5 per cent more in drip irrigation under treatment with good quality water. Averaged over all salinity treatments, it was 12.6 per cent more in case of drip irrigation than in furrow. Average number of tubers for good quality irrigation water (14.8) was at par with EC-2 irrigation treatment. As evident from the graphical representation, compared to irrigation with EC-0 treatment, EC-2, EC-4, EC-6 and EC-8 showed significant and progressive decline in number of tubers per plant in case of furrow and from EC-4 onwards in case of drip irrigation, respectively. At higher salinity treatments, EC-6 and EC-8, the number of tubers per plant were similar under drip and furrow irrigated crop. However, it is worth noting here that significantly heavier tubers were produced under drip irrigation than furrow irrigation suggesting that both, weight of tubers as well as the number are crucial for realizing high tuber yields under saline environments.

### 3.1.5. Yield of potato tubers

Tuber yield is the most important criterion for evaluating and comparing the efficiency of experimental variables because yield is a function of diverse characters like plant growth and yield attributes such as weight of tubers, number of tubers per plant and weight of individual tubers. The results obtained for potato yield (tonnes per hectare) under different irrigation treatments are presented in Table 4.

**Figure 1. Effect of different saline water irrigation treatments on number of tubers per plant under drip and furrow irrigation methods.**



**Table 4. Effect of different saline water irrigation treatments on the yield of potato (in tonnes/hectare) under drip and furrow irrigation methods**

EC (dSm <sup>-1</sup> )	Irrigation method		Mean
	Drip	Furrow	
0	33.07	30.19	31.63
2	32.15	27.11	29.63
4	27.44	18.00	22.72
6	21.52	13.96	17.74
8	18.85	10.93	14.89
Mean	26.61	20.04	
LSD (5%)	EC = 1.37; IM = 1.75; EC × IM = 1.94		

The mean tuber yield was significantly lower in furrow (20.0 t ha<sup>-1</sup>) than drip irrigation (26.61 t ha<sup>-1</sup>). Even under good quality irrigation water, the tuber yield with a value of 30.19 t ha<sup>-1</sup> was significantly lower than under drip irrigation (33.07 t ha<sup>-1</sup>). The data shows significant differences in tuber yield due to various irrigation treatments. Mean tuber yield with good quality irrigation water (31.6 t ha<sup>-1</sup>) was found to be highest, but it was statistically at par to the average yield with EC-2 irrigation treatment (29.63 t ha<sup>-1</sup>). Further increase in levels of salinity of irrigation water showed a significant decrease in yield of tubers.

Under drip irrigation the highest yield (33.07 t ha<sup>-1</sup>) was recorded under good quality water and minimum tuber yield of 18.8 t ha<sup>-1</sup> was observed under EC-8 irrigation water treatment. The data clearly showed a decreasing trend in tuber yield along with the increased level of salinity in irrigation water under both the methods of irrigation. However, the yield under drip irrigation was significantly higher than furrow irrigation at each salinity level of irrigation water. An average increase of 24.7 per cent in yield was observed in drip irrigation over the furrow irrigation. At highest irrigation water salinity (EC-8), yield of drip irrigated potato was 18.8 t ha<sup>-1</sup> and it was similar to the tuber yield obtained at EC-4 in furrow irrigated plots (18.0 t ha<sup>-1</sup>). As pertinent to data in Table 4, in furrow irrigation the reduction in tuber yield was remarkably higher than that in drip irrigation as the level of salinity increased in irrigation water. Thus, the magnitude of increase in yield in drip irrigated plots over furrow irrigated plots establishes the superiority of drip over furrow irrigation in saline irrigated areas. This is due to the fact that increasing salinity also resulted in decrease in weight of tubers per plant, number of tubers per plant and weight of individual tubers, which ultimately resulted in decrease in tuber yield among saline water treatments as compared with good quality water treatment. Tuber yield decreases with increase in salinity of irrigation water due to salt accumulation around the root zone (Nagaz, Toumi, Masmoudi, & Mechlia, 2008; Postel, Polak, Gonzales, & Keller, 2001). Hence, in furrow irrigation due to higher salt concentration near the root zone, the yield was significantly lower than drip irrigation. Due to the formation of wetting front in case of drip irrigation, the rhizospheric environment was conducive for plants to grow without much ionic and osmotic stress.

Thus, the magnitude of increase in yield in drip irrigated plots over furrow irrigated plots establishes the superiority of drip over furrow irrigation in saline irrigated areas. This is due to the fact that increasing salinity treatments also resulted in decrease in weight of tubers per plant, number of tubers per plant and weight of individual tubers per treatments, which ultimately resulted in decrease in tuber yield among saline water treatments as compared with good quality water treatment. Tuber yield decreases with increase in salinity of irrigation water due to salt accumulation around the root zone (Nagaz et al., 2008; Postel et al., 2001). Hence, in furrow irrigation due to higher salt concentration near the root zone, the yield was significantly lower than drip irrigation. Due to the formation of wetting front in case of drip irrigation the rhizospheric environment was conducive for plants to grow without any ionic and osmotic stress.

### 3.1.6. Water use efficiency of crop

Water use efficiency of drip irrigation was higher than furrow irrigation. It was observed that amount of water applied under drip was 25.6 cm and that applied in furrow irrigation was 42.8 cm implying that under drip irrigation saved 40.3 per cent of water. Drip irrigation, not only produces higher yield under saline conditions (Table 4) but also increases the water use efficiency (Table 5). The data shows that water use efficiency is maximum with good quality water under drip irrigated plot. It is evident that lowest value of water use efficiency at maximum salinity (EC-8) under drip irrigation was higher than that of furrow irrigated plots with good quality water (EC-0). Hence, drip irrigation is highly efficient in water use by potato crop over furrow irrigation under saline conditions.

### 3.2. Quality assessment parameters

Quality of the produce was assessed by determining total soluble solids, total sugar and starch content and dry matter content of tubers.

#### 3.2.1. Total soluble solids (TSS)

Total soluble solids (TSS) content of potato was determined as an index of refraction to test the solids concentration of a sucrose containing solution. The data shown in Table 6 depicts that the TSS was significantly affected by salinity of irrigation water. It was observed to be decreasing with the increasing salinity of irrigation water for both the methods of irrigation. On an average, the highest TSS was 7.5 obtained for the tubers irrigated with good quality water. It significantly decreased at EC-2, EC-4, EC-6 and EC-8 treatments. However, no significant difference in TSS was observed between the two methods of irrigation. The reduction in TSS due to irrigation with poor quality saline water was mainly due to inhibited effect of accumulation of solutes in the presence of higher content of carbonates and chlorides (Choudhary, Ghuman, Dhaliwal, & Chawla, 2010).

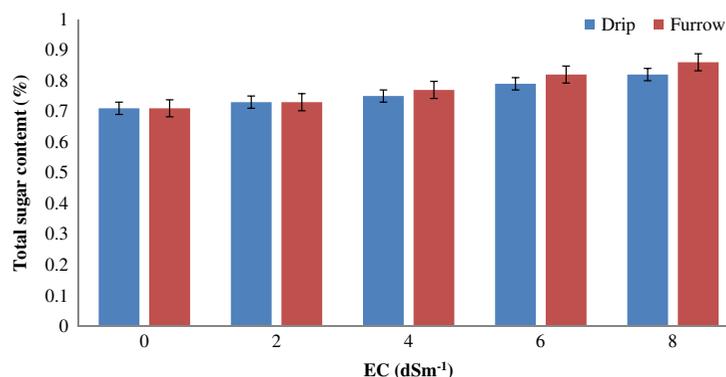
**Table 5. Effect of saline water irrigation treatments on water use efficiency of crop**

EC (dSm <sup>-1</sup> )	Depth of applied water (in cm)		Water use efficiency (kg/ha-cm)	
	Drip	Furrow	Drip	Furrow
0	25.6	42.8	1,291.8	705.4
2	25.6	42.8	1,255.9	633.4
4	25.6	42.8	1,071.9	420.6
6	25.6	42.8	840.6	326.2
8	25.6	42.8	736.3	255.6

**Table 6. Effect of different saline water irrigation treatments on the total soluble solids (TSS) of potato under drip and furrow irrigation methods**

EC (dSm <sup>-1</sup> )	Irrigation method		Mean
	Drip	Furrow	
0	7.93	7.07	7.50
2	6.10	5.97	6.03
4	5.13	5.50	5.32
6	4.97	4.73	4.85
8	4.17	4.43	4.25
Mean	5.66	5.52	
LSD (5%)	EC = 0.7228; IM = NS; EC × IM = NS		

**Figure 2. Effect of different saline water irrigation treatments on total sugar content (%) of potato tubers under drip and furrow irrigation methods.**



### 3.2.2. Total sugar content

Unlike TSS, sugar content in potato tubers was found to increase significantly with increase in salinity of irrigation water (Figure 2). Mean sugar content in potato tubers with good quality irrigation water was determined as 0.71 per cent that proved to be the significantly lowest value compared with EC-2, EC-4, EC-6 and EC-8 irrigation treatments. Average sugar content under drip irrigation was 0.76 per cent and that under furrow irrigation was slightly higher with a value of 0.78 per cent. This difference was small but it was significant. Higher value of sugar content of 0.86 per cent was observed under EC-8 irrigation under furrow irrigation. At all salinity levels, drip irrigated potato had significantly lower sugar content than furrow irrigated potatoes.

The tubers of potato show negative trends in total soluble solids but high sucrose values of tubers under NaCl stress. It may be due to the fact that the negative effects of salinity on potato tuberization were a consequence of the reduction in osmotic potential due to increasing salt levels in cells of tuber tissues which led to a reduction of water content and nutrient uptake in tubers, resulting in lower metabolic activities of plant leading to lower TSS and accumulation of sugar in the cells. The activity of invertase enzyme increases under salt stress. This is associated with the increased amount of total sugar content in potato (Richardson, Davies, Ross, & Mackay, 1990; Uppal & Verma, 1990).

### 3.2.3. Starch content

Starch content significantly decreased with increasing salinity of irrigation water (Table 7). But it was not influenced by methods of irrigation. The interaction was also observed to be non-significant. Mean value of starch content did not decrease up to EC-2 treatment. However, it decreased significantly with further increase in salinity. The results were in accordance with the findings of Sasikala and Deviprasad (1994). In their study, different genotypes of potato showed decreasing starch content with increase in levels of salt content in irrigation water. The oxidative stress due to saline conditions led to reduction in synthesis of starch.

**Table 7. Effect of different saline water irrigation treatments on the starch content (%) of potato**

EC (dSm <sup>-1</sup> )	Irrigation method		Mean
	Drip	Furrow	
0	15.24	15.11	15.17
2	15.13	15.08	15.11
4	15.03	14.59	14.81
6	14.21	13.92	14.01
8	13.6	13.67	13.63
Mean	14.62	14.47	
LSD (5%)	EC = 0.38; IM = NS; EC × IM = NS		

### 3.2.4. Dry matter content

Dry matter content of the tubers exhibited a significantly decreasing trend with increase salinity in irrigation water (Table 8). Dry matter content was higher at 16.4 per cent under drip irrigation, relative to 15.5 per cent in case of furrow irrigation, the differences were, however non-significant.

### 3.2.5. Grading of tubers

Grading is important for assessment and sorting of tubers which determines their quality, freshness and market value. Variability in number of tubers in four grades was observed for different irrigation treatments and methods (Table 9). The proportion of different grades under saline water irrigation treatment have been graphically represented in Figure 3. Mean Grade A tubers were reported to be significantly higher in number in case of drip irrigation (101,110 ha<sup>-1</sup>) than furrow irrigation (38,890 ha<sup>-1</sup>). Expectedly, number of tubers of this grade were highest in treatment with good quality water (126,390 ha<sup>-1</sup>) and was statistically at par to EC-2 treatment (93,060 ha<sup>-1</sup>). But it decreased at higher salinities of irrigation water as observed under EC-4, EC-6 and EC-8 treatments. Interaction between salinity treatments and irrigation methods were significant for Grade A tubers. Even at higher salinity levels Grade A tubers were more in number under drip irrigation than furrow

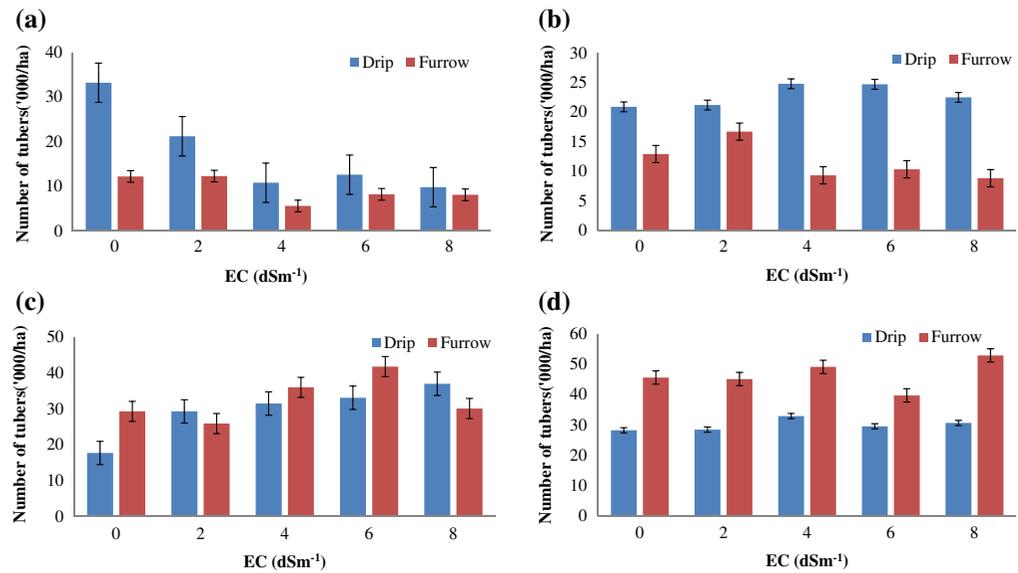
**Table 8. Effect of different saline water irrigation treatments on the dry matter content (%) of potato tubers**

EC (dSm <sup>-1</sup> )	Irrigation method		Mean
	Drip	Furrow	
0	17.48	16.96	17.22
2	16.97	16.88	16.92
4	16.69	15.62	16.15
6	15.95	14.03	14.99
8	14.85	13.99	14.42
Mean	16.39	15.50	
LSD (5%)	EC = 0.54; IM = NS; EC × IM = NS		

**Table 9. Effect of different saline water irrigation treatments on different grades of tubers expressed as grade-wise tuber population ('000/ha)**

EC (dSm <sup>-1</sup> )	Irrigation method		Mean	EC (dSm <sup>-1</sup> )	Irrigation method		Mean
	Drip	Furrow			Drip	Furrow	
Grade-A (more than 75 g)				Grade-B (between 50–75 g)			
0	202.78	50.00	126.39	0	127.78	52.78	90.28
2	130.56	55.56	93.06	2	130.56	75.00	102.78
4	66.67	25.00	45.83	4	152.78	41.67	97.22
6	58.33	33.33	45.83	6	113.89	41.67	77.78
8	47.22	30.56	38.89	8	108.33	33.33	70.83
Mean	101.11	38.89		Mean	126.67	48.89	
LSD (5%)	EC = 31.79; IM = 48.52; EC × IM = 44.96			LSD (5%)	EC = NS; IM = 31.35; EC × IM = NS		
Grade-C (between 25–50 g)				Grade-D (less than 25 g)			
0	108.33	119.44	113.89	0	172.22	200.00	186.11
2	180.56	116.67	148.61	2	175.00	230.56	202.78
4	194.44	161.11	177.78	4	202.78	236.11	219.44
6	152.78	169.44	161.11	6	136.11	186.11	161.11
8	177.78	113.89	145.83	8	147.22	252.78	200.00
Mean	162.78	136.11		Mean	166.67	221.11	
LSD (5%)	EC = NS; IM = NS; EC × IM = NS			LSD (5%)	EC = NS; IM = 51.77; EC × IM = NS		

**Figure 3. Effect of different saline water irrigation treatments on proportion (%) of different grades of tubers (a) Grade-A (b) Grade-B (c) Grade-C (d) Grade-D.**



irrigation. The levels of salinity of irrigation water treatments had non-significant impact on numbers of Grade B tubers. However, there were significantly higher number of Grade B tubers (126,670 ha<sup>-1</sup>) in drip than furrow irrigation (48,890 ha<sup>-1</sup>). Similar to Grade A, Grade B tubers were higher under drip irrigation than furrow irrigation at higher salinity of irrigation water. The salinity treatments of irrigation water as well as the irrigation methods had non-significant impact on number of Grade C tubers. It was almost equally distributed over different treatments and irrigation methods. Mean number of Grade D tubers were significantly higher under furrow irrigation method (221,110 ha<sup>-1</sup>) than drip irrigation (166,670 ha<sup>-1</sup>). Highest number Grade-A tubers (more than 75 g) were recorded for drip irrigation under treatment with good quality water. However, B grade (between 50 and 75 g) tubers were dominant in EC-2 and EC-4 treatments of drip irrigation method. Subsequently, C grades (between 25 and 50 g) were predominant in EC-6 and EC-8 irrigation treatments of both drip and furrow irrigation method, while D grade (less than 25 g) potato were observed to be more in numbers under EC-6 and EC-8 irrigation treatments of furrow irrigation method.

Proportionately, Grade-A tubers were observed to decrease significantly as the levels of salinity increased. Also Grade-A tubers were lower in furrow irrigation than drip by 61 per cent. Similar trend was observed for Grade-B tubers which also exceeded by 61.4 per cent in case of drip over furrow irrigation method. Contrastingly, Grade-C tubers were almost equally distributed in both the irrigation methods and showed a non-significant difference in between two methods of irrigation. Grade-D tubers were found to increase with increase in levels of salinity and thus, observed to be more in EC-8 treatment of furrow method by 24 per cent than drip system of irrigation. These results clearly suggest that drip irrigation even while using saline water is able to produce potato tubers of better grade than furrow irrigation.

#### 4. Conclusions

The restricted movement of water in soils irrigated with saline water result in retention of salt in surface layers around the root zone that induces salinity stresses affecting crop growth. In drip irrigation due to formation of wetting front by the movement of water, salts are pushed away towards the periphery of the front. This provides better plant growth under drip irrigation using saline water. Therefore, plant height was observed to decrease with increasing salinity. However, under drip irrigation it was more when compared to furrow irrigation at higher salinity. Weight of tubers per plant decreased significantly as the salinity of irrigation water increased. Tuber weight was observed to be higher in case of drip irrigation. Number of tubers also decreased with increase in salinity apart from

the weight of tubers per plant. Tuber yield significantly decreased with increase in salinity of irrigation water. Yield was observed to be significantly higher in case of drip irrigation than furrow irrigation. All yield attributes had higher values under drip irrigation than furrow irrigation even at higher salinity. With increase in salinity of irrigation water TSS, starch and dry matter content of tubers decreased, however sugar content increased, thereby negatively affecting the quality of tubers. Grade A and B tubers decreased proportionately with salinity. However number of Grade C and D tubers increased with increase in salinity. The proportion of Grade A and B tubers were found to be more in case of drip irrigation while proportion of lower grades, Grade C and Grade D tubers were observed to be more in furrow irrigation.

#### Funding

The project was supported by the Precision Farming Development Centre, Research cum Demonstration farm, Department of Soil & Water Engineering, PAU, Ludhiana and funded under the scheme "Centre of excellence for utilization of brackish water for fruit and vegetable production".

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#### Citation information

Cite this article as: Comparative effects of saline water on yield and quality of potato under drip and furrow irrigation, Gaurav Jha, O.P. Choudhary & Rakesh Sharda, *Cogent Food & Agriculture* (2017), 3: 1369345.

#### Cover image

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