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Salt Accumulation and Leaching Requirement for Saline Irrigation: A Comparative Study of Surface and Drip Irrigation Methods

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Abstract

Irrigation with saline water results in the build-up of soil salinity and reduces crop yield. Irrigation method influences amount of salt added to soil through irrigation. In this study, salt additions to crop root zone by both surface and drip method were computed and leaching requirement (LR) in both cases were estimated. The data of cauliflower experiment conducted at Hisar in Haryana where crop was grown with 0.4, 2.5, 5.0 and 7.5 dS m^{-1} levels of irrigation water salinities (EC_{iw}) under surface and drip irrigation used in this study. As experimental results cauliflower tolerated 3.2 and 5.9 EC_{iw} (dS m^{-1}) under surface and drip irrigation, respectively. Overall, cauliflower yield was 13.64-42.86% higher in drip irrigation as compared to surface irrigation. However, the salt accumulation was 22-23% lower, and LR was 38-42% lower in drip irrigation than the surface irrigation. It was observed that cauliflower tolerated higher level of EC_{iw}, with lower salt accumulation and LR as compared to surface irrigation system. The results would be helpful in convincing vegetables growers to use drip in case of saline water irrigation as it would give more yield per drop of water while using higher saline water at lower level of salinization.

Key words: Saline water, Micro irrigation, Salinity development, Yield loss, Leaching requirement

Introduction

The poor quality groundwaters occur worldwide especially in arid and semi-arid areas and broadly classified into saline water (with excess salt) and alkali water (with residual alkalinity) on basis of quality parameters (Minhas, 1996). Poor-quality groundwater ranges from 32 to 84% of total irrigation water in different Indian states, and saline water contributed 37% to the total poor-quality groundwater (Gupta *et al.,* 1994). In view of the unexpected change in long-term rainfall pattern under climate change scenario, there would be decrease in rainfall amounts as well as number of rainy days affecting availability of good quality waters (IPCC, 2014). The limited availability of good quality waters in arid and semi-arid regions would compel farmers to use saline waters for irrigation (Rhoades *et al.,* 1992; Shani and Dudley, 2001). Irrigation with saline water leads to development of root zone salinity and plants face salinity stress due to increased level of salts in soil solution. Generally, crop tolerates soil salinity up to a certain level called as threshold salinity (EC_e) and above which yield decreases linearly (Maas and Hoffman, 1977).

The sustainable crop production through saline water can only be achieved with judicious management of soil, crop and water. It is very important to maintain root zone salinity at low level, well below the crop tolerance limit. There can be three approaches to do so. First approach is leaching of excess salts with good quality water (Oron *et al.,* 2002); second approach is use of salt tolerant crops or varieties that can tolerate high level of salinity stress (de Lacerda *et al.,* 2005); and third approach is use of drip irrigation which supply only sufficient amount of water to meet the evaporative demand of crop and minimize the

Table 1. Details of cauliflower experiment conducted at Hisar centre of AICRP (on Salt Affected Soils and Use of Saline Water) during 2014-15

Particulars	Drip irrigation				Surface irrigation			
Irrigation water salinity EC_{iw} (ds m^{-1})	0.4	2.5	5.0	7.5	0.4*	2.5	5.0	7.5
Cauliflower yield (Mg ha^{-1})	43.57	43.25	41.39	36.6	38.34	36.72	32.63	33.33
Amount of irrigation water applied (mm)	245	245	245	256[a]	314	314	314	333[a]
Leaching fraction	0.15[b]							

*Represent the salinity of best available water (canal water)
[a]Higher amount of irrigation was applied due to delayed maturity
[b]LR for the sandy loam soil was assumed as 0.15
Source: Kaledhonkar *et al.* (2017)

salt accumulation in the crop root-zone (Fischer, 1980; Munns, 2002). Leaching of accumulated salts in active root zone with good quality water is the most effective approach to control the soil salinity. However, the possibilities of leaching of excess salt with good quality water are limited in poor quality groundwater areas. Therefore, use of drip irrigation system could be better option for management of saline waters as well as soil salinity in the crop root zone. It would be logical to assume that the amount of salt added and subsequent build-up of soil salinity under drip irrigation method could be lower than the surface irrigation method. With this background, an attempt was made to estimate the salt accumulation and subsequent leaching requirement (LR) of root zone under drip and surface irrigation method using saline water irrigation in case of cauliflower crop.

Materials and Methods

Data source

To estimate the total salt accumulation due to saline water irrigation and leaching requirement (LR) of cauliflower crop, the secondary data of cauliflower experiment conducted at Hisar centre of AICRP on Management of Salt Affected Soils and Use of Saline Water (SAS & USW) in Agriculture were obtained from the Biennial Report of the AICRP (Kaledhonkar *et al.,* 2017). The experiment was conducted at experimental farm of AICRP on SAS & USW, Hisar. The climate of the region is semi-arid type with long-term average annual rainfall of 470 mm (Anurag *et al.,* 2017). The soil of experimental site is sandy loam (sl) in texture with 63.5% sand, 17.3% silt, and 19.2% clay content. The experimental data obtained from the AICRP report are presented in the Table 1.

Salt accumulation in crop root zone

Total amount of salt accumulated in the crop root zone as results of saline water irrigation under drip and surface method was estimated using the Grattan (2002) equation (1)

$$\text{Salt accumulation (mg)} = \{TDS_{iw}\,(\text{mg l}^{-1}) \times V_{iw}\,(\text{l})\} - \{TDS_{dw}\,(\text{mg l}^{-1}) \times V_{dw}\,(\text{l})\} \quad \ldots(1)$$

Here, TDS_{iw} is concentration of total dissolved salt (TDS) in irrigation water; TDS_{dw} is concentration of TDS in drainage water; V_{iw} is volume of irrigation water, and V_{dw} is volume of drainage water.

The V_{iw} and V_{dw} were computed using equations (2) and (3), respectively.

$$V_{iw} = \frac{\text{Amount of water applied}}{1\text{-LF}} \quad \ldots(2)$$

$$V_{dw} = V_{iw} \times LF \quad \ldots(3)$$

Where, LF is leaching fraction i.e. desired leaching level. The LF for sandy loam soil of Hisar region is considered as 0.15 (Ayers and Westcot, 1985).

The TDS_{iw} and TDS_{dw} were calculated using equations (4) and (5).

$$TDS_{iw} \text{ or } TDS_{dw}\,(\text{mg l}^{-1}) = 640 \times EC_{iw} \text{ or } EC_{dw}\,(\text{dS m}^{-1}) \quad \ldots(4)$$

$$TDS_{iw} \text{ or } TDS_{dw}\,(\text{mg l}^{-1}) = 800 \times EC_{iw} \text{ or } EC_{dw}\,(\text{dS m}^{-1}) \quad \ldots(5)$$

Equation (4) is used when EC_{iw} is less than 5, and equation (5) is used when EC_{iw} is more than 5. Generally, the conversions factors (640 & 800) between EC_{iw}/EC_{dw} and TDS are depending on the salinity and composition of the water. Therefore, the caution is advised during the conversions.

It is assumed that salinity of drainage water (EC_{dw}) is equivalent to the soil-water salinity (EC_{sw}). Therefore, the EC_{dw} was estimated using equation (6).

$$EC_{dw} = EC_{sw} \quad ...(6)$$

The EC_{sw} is the average root zone salinity to which the plant is actually exposed. It is difficult to measure the EC_{sw}. Generally, soil salinity is measured on a saturation extract basis and referred to as the EC_e. This EC_e, EC_{sw} and EC_{iw} are interconvertible. The EC_e is approximately equal to one-half of the EC_{sw}. As a thumb rule, at a 0.15 LF, EC_{iw} can be used to estimate the EC_{sw} or EC_e using the equations (7), (8) and (9):

$$EC_{sw} = 3\ EC_{iw} \quad ...(7)$$

$$EC_e = 1.5\ EC_{iw} \quad ...(8)$$

$$EC_{sw} = 2\ EC_e \quad ...(9)$$

The equation for predicting the $EC_{e,}$ expected after several years of irrigation with saline water is mention as equation (10)

$$EC_e\ (\text{dS m}^{-1}) = EC_{iw}\ (\text{dS m}^{-1}) \times X \quad ...(10)$$

Where, X is the concentration factor, which is based on four things, i) irrigation water salinity (EC_{iw}), ii) crop evapotranspiration demand (ET), iii) crop water use pattern, and iv) desired leaching fraction (LF). The crop water use pattern was assumed as 40-30-20-10, it means, crop gets 40% of its water requirement from upper quarter of crop root zone, 30% from next quarter, 20% from next quarter and 10% from the lowest quarter. In present study, crop ET for cauliflower was taken as 370 mm (Sahin *et al.,* 2009), effective root zone for cauliflower was considered as 30 cm, and LF for sandy loam soil was taken as 0.15 (Ayers and Westcot, 1985). Therefore, considering these factors, the concentration factor (X) for estimating soil salinity was taken as 1.6 (Ayers and Westcot, 1985).

Leaching requirement

The leaching requirement (LR) of cauliflower crops was estimated using equation (11) (Rhoades, 1974).

$$LR = \frac{EC_{iw}}{5\,(EC_e)-EC_{iw}} \quad ...(11)$$

Here, LR is the minimum amount of water required to control the salt concentration within the crop tolerance limit; EC_{iw} is the irrigation water salinity (dS m^{-1}), and EC_e is the soil salinity of saturation extract tolerated by the crops. In present study, we used irrigation water salinity for 90% relative yield as crop threshold salinity (EC_e).

The equation (11) is applicable for the surface irrigation methods and long-term equilibrium with irrigation water salinity within root zone is assumed. Basically vertical movement of water and salts takes place in surface irrigation method. In case of drip irrigation method, water and salt movement takes place both horizontal as well as vertical direction. Thus, assumption of vertical movement in equation (11) is not fully achieved in drip irrigation method. Simplification of real life conditions of water and salt movement in case of drip irrigation was necessary for comparison of salt accumulation and LR under drip and surface irrigation method. Under simplified conditions, equation (11) was adopted for drip irrigation. It is assume that in case of rainfall or application of good quality water for leaching, the salts will redistribute and then vertical movement of salts will takes place.

Results and Discussion

Crop yield and salinity-yield relationship

The salinity-yield relationship of cauliflower under drip and surface irrigation method are presented in Fig. 1. Highest crop yield 43.57 Mg ha^{-1} in drip irrigation (Fig. 1a) and 38.34 Mg ha^{-1} in surface irrigation (Fig. 1b) was recorded in best available water (0.4 dS m^{-1}) treatment. In rest of the treatment, crop yield decreased with increased salinity of irrigation water (EC_{iw}) under both drip and surface irrigation. The reduction in crop yield was 0.7%, 5.0%, and 16.0% in drip irrigation, and

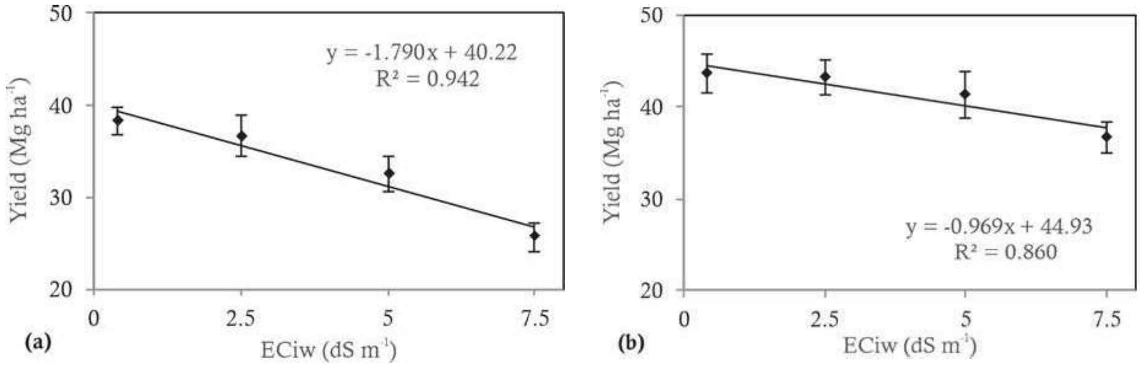

Fig. 1 Salinity yield relationship for cauliflower under a) surface irrigation and b) drip irrigation methods

4.2%, 14.9% and 33.2% in surface irrigation under 2.5, 5.0 and 7.5 dS m^{-1} EC_{iw}, respectively. Using salinity-yield relationship presented in Fig. 1, the EC_{iw} were worked out for 90%, 75% and 50% relative yield. Cauliflower tolerated higher level of irrigation water salinity (EC_{iw}) in drip irrigation (5.9 dS m^{-1}) as compared to surface irrigation (3.2 dS m^{-1}). In drip irrigation, 90%, 75% and 50% relative yield of cauliflower were obtained at 5.9, 12.6 and 23.9 EC_{iw} (dS m^{-1}). In surface irrigation, 90%, 75% and 50% relative yield were obtained at 3.2, 6.4 and 11.7 EC_{iw} (dS m^{-1}). The values of irrigation water salinities in drip irrigation were almost two times the values of surface irrigation.

Salt accumulation in crop root zone

Computation of salt accumulation in the crop root zone was based on the LF of the sandy loam soil, amount of irrigation water applied, and crop evapotranspiration (ET) of cauliflower. The 0.15 was used as LF for sandy loam soil (Ayers and Westcot, 1985). The amount of irrigation water applied was 314 mm in surface irrigation method, and 245 mm in drip irrigation method in 0.4, 2.5, and 5.0 dS m^{-1} irrigation water salinity (EC_{iw}) treatments. In case of 7.5 dS m^{-1} treatment, higher amount (333 mm in surface, and 256 mm in drip) of irrigation water was applied due to delayed crop maturity. The crop evapotranspiration (ET) demand of cauliflower crop in semi-arid region was about 332.5 mm (Sahin *et al.,* 2009). In, present study, total amount of irrigation water applied was lower than the crop ET demand. So, it is assumed that, no water was leached out beyond the crop root-zone and all salts in irrigation water were accumulated in the crop root zone only.

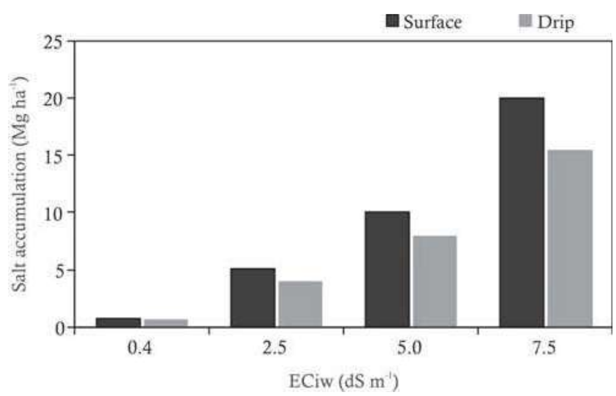

Fig. 2 Salt accumulation in crop root zone under surface irrigation and drip irrigation methods

Total salt load was estimated 0.80, 5.02, 10.05 and 19.98 Mg ha^{-1} in surface irrigation and 0.63, 3.92, 7.84 and 15.36 Mg ha^{-1} in drip irrigation at 0.4, 2.5, 5.0 and 7.5 dS m^{-1} irrigation water salinities (EC_{iw}), respectively (Fig. 2). Salt accumulation in crop root zone is mainly depends upon the quantity (amount) and quality (salinity) of the irrigation water applied. Salt load increased with increased salinity of irrigation water (EC_{iw}) irrespective of the irrigation method. It was mainly because of the higher salinities of irrigation water. Overall, salt accumulation was higher in surface irrigation as compared to drip irrigation. It is mainly because of the higher amount of irrigation water was applied in surface irrigation as compared to drip irrigation. Overall, the salt accumulation was 22-23% lower in drip irrigation as compared to surface irrigation method.

Leaching requirement

Crop production using saline irrigation water is depends on the crop root zone salinity. In order to ensure the sustainable crop production using saline water, it is necessary to leach out the excess salts from the crop root zone for keeping soil salinity within crop tolerance limit. In present study, we worked out the leaching requirement (LR) to keep the soil salinity within the crop tolerance limit. LR was estimated 0.5, 3.7, 8.3 and 15.1 cm in surface irrigation and 0.3, 2.3, 5.0 and 8.7 cm in drip irrigation at 0.4, 2.5, 5.0 and 7.5 dS m^{-1} EC_{iw}, respectively (Fig. 3). The LR of surface irrigation was almost twice the LR of drip irrigation for all the irrigation water salinities (EC_{iw}). Overall LR for drip irrigation is 38-42% lower than the LR of surface irrigation method.

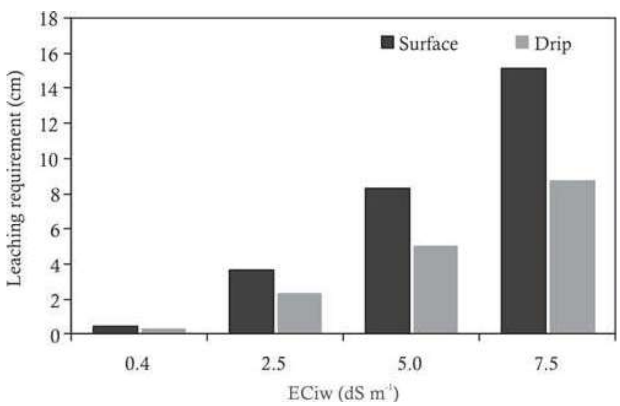

Fig. 3 Leaching requirement (LR) to leached out the excess salts from crop root zone under surface irrigation and drip irrigation method

The long-term average annual rainfall of the Hisar region is 470 mm and most of which is occurs during the monsoon season (July-Sept) (Anurag *et al.,* 2017). The highest LR of cauliflower crop was 151 mm in surface irrigation method, and 87 mm in drip irrigation method in 7.5 dS m^{-1} EC_{iw} treatment. Therefore, the amount of monsoon rainfall is sufficient for leaching of excess salts from the crop root-zone for sustainable cauliflower production in the region. Although, excess salt from both the methods can be removed by the monsoon rainfall, drip irrigation method is more suitable for the cauliflower due to higher crop yield and lower salt accumulation.

Conclusions

In the Hiasr region of Haryana cauliflower can be grown with the saline water irrigation up to 7.5 dS m^{-1} irrigation water salinity under both drip and surface irrigation method. However, cauliflower tolerated higher level of irrigation water salinity in drip irrigation method, and significantly higher yield was also achieved. Both salt accumulation in crop root zone, and leaching requirement of cauliflower is lower in drip irrigation methods. Overall drip irrigation method performed better as compared to surface irrigation method using saline water for irrigation of cauliflower crop. The results would be helpful in convincing vegetables growers to use drip in case of saline water irrigation as it would give more yield per drop of water while using higher saline water at lower level of salinization.

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References

Anurag, Kumar A, Singh D, Singh R, Singh S and Shekhar C (2017) Evaluating Rainfall Trends at Hisar (Haryana) in the Semi-arid Zone of North India. *Annals of Arid Zone* **56(3&4):** 83-87.

Ayers RS and Westcot DW (1985) *Water Quality for Agriculture*. Food and Agriculture Organization of the United Nations, Rome.

de Lacerda CF, Cambraia J, Oliva MA, Ruiz HA (2005) Changes in growth and in solute concentrations in sorghum leaves and roots during salt stress recovery. *Environmental and Experimental Botany* **54(1):** 69–76.

Fischer RA (1980) Influence of water stress on crop yield in semiarid regions. In: Turner NC and Kramer PJ (eds) *Adaptation of Plants to Water and High Temperature Stress*. Wiley and Sons, New York, pp 323–340

Grattan S (2002) *Irrigation Water Salinity and Crop Production* (Vol. 9). UCANR Publications.

Gupta RK, Singh NT and Sethi M (1994) *Ground Water Quality for Irrigation in India*. Technical Bulletin No. 19. Central Soil Salinity Research Institute, Karnal, 13p.

IPCC (2014) *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects*. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros VR, Field CB, Dokken DJ, Mastrandrea MD, Mach KJ, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR and White LL (eds)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 688 pp.

Kaledhonkar MJ, Meena RL, Meena BL and Fagodiya RK (2017) *Biennial Report (2014-16)*: All India Coordinated Research Project on Management of Salt Affected Soils and Use of Saline Water in Agriculture. ICAR-Central Soil Salinity Research Institute, Karnal, 230p.

Maas EV and Hoffman GJ (1977) Crop salt tolerance, current assessment. *Journal of the Irrigation and Drainage Division* **103(2):** 115–134.

Minhas PS (1996) Saline water management for irrigation in India. *Agriculture Water Management* **30:** 1–30.

Munns R (2002) Comparative physiology of salt and water stress. *Plant, Cell & Environment* **25(2):** 239–250.

Oron G, DeMalach Y, Gillerman L, David I and Lurie S (2002) SW—soil and water: effect of water salinity and irrigation technology on yield and quality of pears. *Biosystems Engineering* **81(2):** 237–247.

Rhoades JD (1974) Drainage for salinity control. *Drainage for Agriculture* **17:** 433–61.

Rhoades JD, Kandiah A and Mashali AM (1992) The use of saline waters for crop production-FAO irrigation and drainage paper 48. FAO, Rome, 133.

Sahin U, Kuslu Y, Tunc T and Kiziloglu FM (2009) Determining crop and pan coefficients for cauliflower and red cabbage crops under cool season semiarid climatic conditions *Agricultural Sciences in China* **8(2):** 167–71.

Shani U and Dudley LM (2001) Field studies of crop response to water and salt stress. *Soil Science Society of America Journal* **65(5):** 1522–1528.

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