Available online at www.ijpab.com

DOI: http://dx.doi.org/10.18782/2582-2845.7987

ISSN: 2582 – 2845

Ind. J. Pure App. Biosci. (2020) *8*(1), 262-271

Review Article

Indian Journal of Pure & Applied Biosciences

Peer-Reviewed, Refereed, Open Access Journal

A Review: Use of Saline Water in Irrigation for Agriculture

Ashish Kumar[1*], Mukesh Kumar Mehla[2] and Sanjay Kumar[3]

[1]Senior Research Fellow, Department of Soil and Water Engineering,
College of Agricultural Engineering and Technology, PAU, Ludhiana, Punjab, India
[2]Ph.D Scholar, Department of Soil and Water Engineering,
College of Technology and Engineering, MPUAT, Udiapur, Rajasthan, India
[3]Professor and Head, Department of Soil and Water Engineering,
College of Agricultural Engineering and Technology, CCSHAU, Hisar, Haryana, India
*Corresponding Author E-mail: kamboashish@gmail.com

Received: 9.01.2019 | Revised: 16.02.2020 | Accepted: 23.02.2020

ABSTRACT

The shortage of water resources of good quality is becoming a main issue in the arid and semi-arid zones. Approximately 32 to 84% area under arid and semi-arid states is covered under saline or alkali groundwater. In Haryana, poor quality waters are 55%. Among the poor quality waters 18% were sodic, 11% saline and 26% were saline-sodic. Use of poor quality water for irrigation is a strategy to overcome the water shortage. For this reason the availability of water resources of marginal quality groundwater has become an important consideration. Therefore, irrigation with saline water requires a comprehensive analysis even beyond the area where water is applied. For studied many research papers, we found that conjunctive use of saline water (SW) and fresh water (FW) is best for crop production. Results showed that the conjunctive use of saline and non-saline water can increase the irrigation water use efficiency (IWUE) with a little reduction in crop yield compared to constant use of saline water for irrigation. In addition of conjunctive use, salt tolerant verities should be adopted to minimize the effect of salinity.

Keywords: *Saline water, Fresh water, Poor quality water, Marginal quality water, Salt tolerant verity*

INTRODUCTION

Irrigated agriculture consumes 60 to 80% of the total water usages and contributes nearly in 38 percent of the global food production. It has played a major role in generating employment opportunities in the rural areas and providing food at cheap prices for low income families and middle class ones in the urban area. Wordwild during eighties and late nineties irrigated agriculture lands have considerably increased. According to FAO data, it is projected to further increase in the next 34 years. This indicates that irrigation sector uses a large share of the entire global water, whereas, also the demand for irrigation water is going to rise in the coming years (Shahinasi & Kashuta, 2008).

Cite this article: Kumar, A., Mehla, M.K., & Kumar, S. (2020). A Review: Use of Saline Water in Irrigation for Agriculture, *Ind. J. Pure App. Biosci. 8*(1), 262-271. doi: http://dx.doi.org/10.18782/2582-2845.7987

World's global water resources accounts for 97.5% out of which 2.5% fresh water resources in which India fresh water resources accounts for 7 to 17% which is inclusive of both surface (64%) and ground water resources (36%). In India, out of available water 5, 6 and 89 percent are being utilized in domestic, industries and agricultural purposes, respectively (Devojee et al., 2018). Increase in the agricultural production has become very essential to manage the food requirement of increasing world population (Chen et al., 2011). Due to decrease in availability of fresh water for agricultural production (Cai & Rosegrant, 2003), use of saline water for irrigation purpose is the only way to manage irrigation requirements. The adaptability of saline irrigation is decided by crop salt-tolerance limit, nature of soil, quality of saline water, intensity of rainfall, leaching characteristics, availability of fresh water, method of application of irrigation water, climate of the area, soil-water-crop environment and human resource management practices as well as the saline water irrigation economics (Dagar & Minhas 2016). There are a number of factors to be considered when using saline water i.e. plant tolerance, irrigation system, water management strategies, irrigation frequency and soil properties (Malash et al., 2005). Salt stress causes water scarcity as a result of osmotic effects on metabolic activities of the plants and this water scarcity results in oxidative stress because of the formation of reactive oxygen species (Gupta et al., 2017).

The state of Haryana (44000 km^2) lies in the north western part of India on the watershed between the Ganges and Indus river basins. Nearly the whole state lies in the Indo-Gangetic plain and is an important food grain producer. About 80% of the state's area is agricultural land (Tanwar & Kruseman, 1985). In Haryana ground water was classified as 37% good, 8% marginal and 55% as poor quality waters. Among the poor quality waters 18% were sodic, 11% saline and 26% were saline-sodic. Majority of tube-well waters contain high concentration of salts and their continuous use for irrigation badly affects the soil health and agricultural production. It necessitates continuous monitoring of groundwater for assessing the possible damage on salinity and alkalinity induced soil health (Shahid et al., 2008).

Groundwater Quality

Problems of poor quality water are generally associated with arid and semi-arid regions and in coastal aquifers. Approximately 32 to 84% area under arid and semi-arid states is covered under saline or alkali groundwater (Minhas, 1996). Table 1 shows the ground water quality in select states of India. Groundwater surveys in India indicate that poor-quality water being utilized in different states is 25 to 84% of the total groundwater development, more in arid and semiarid regions. It is 84% in Rajasthan, 62% in Haryana, 47% in Uttar Pradesh, 38% in Karnataka, 30% in Gujarat, 32% in Andhra Pradesh, and 25% in Madhya Pardesh (Minhas, 1998). Groundwater quality contributing to soil salinisation is grouped into seven classes, *viz*. good, marginally saline, saline, high-SAR saline, marginally alkali, alkali and highly alkali waters (Table 2) based on EC, SAR and RSC (residual sodium carbonate) as criteria for suitability of irrigation (Minhas & Gupta, 1992).

Table 1: Groundwater (GW) quality in select states of India

State	Utilizable ground water resource (M ha-m yr^{-1})	Use of poor quality waters (M ha-m yr^{-1})	Area underlain by saline GW (EC > 4dS/m)
Punjab	1.47	0.68	3058
Haryana	0.86	0.47	11438
U. P.	6.31	1.42	1362
Rajasthan	0.95	0.65	141036
Gujarat	1.56	0.26	24300
Karnataka	1.24	0.17	8804
Tamil Nadu	2.02	NA	3300
All India	32.63	NA	19348

(Source: http://www.cssri.org/index.php?option=com_content&view=article&id=77&Itemid=77)

Table 2: Guidelines for suitability of groundwater quality for irrigation

Sr. No.	Water quality		EC (dS m^{-1})	SAR (m-mol l^{-1})$^{1/2}$	RSC (me l^{-1})
1.	Good		<2	<10	<2.5
2.	Saline waters	Marginally saline	2-4	<10	<2.5
		Saline	>4	<10	<2.5
		High-SAR saline	>4	>10	<2.5
3.	Alkali waters	Marginally alkali	<4	<10	2.5-4.0
		Alkali	<4	<10	>4.0
		Highly alkali	Variable	>10	>4.0

In judging the suitability of saline water for irrigation, one should account for the varying sensitivity of the plants at different growth stages to the salinity of the irrigation water (Malash et al., 2005). Rhoades et al. (1992) and Minhas and Gupta (1992) created the standard water quality criteria for saline water irrigation. Ragab (1998) critically examined the possibilities and constraints in the use of brackish water for irrigation and merits of sprinkler and drip irrigations for the saline water use. Kandiah (1998) derived strategies to minimize adverse environmental impacts of the saline water use in agriculture. The guidelines recommended for productive use of saline irrigation water are given in Table 3.

Table 3: Guidelines for saline irrigation waters (RSC < 2.5 me l^{-1}) in India

Soil texture (% clay)	Crop tolerance	Upper limits of EC_{iw} (dS/m) in rainfall (mm) region		
		<350 mm	350–550 mm	550–750 mm
Fine soil (>30 %)	Sensitive	1.0	1.0	1.5
	Semi-tolerant	1.5	2.0	3.0
	Tolerant	2.0	3.0	4.5
Moderately fine soil (20–30 %)	Sensitive	1.5	2.0	2.5
	Semi-tolerant	2.0	3.0	4.5
	Tolerant	4.0	6.0	8.0
Moderately coarse soil (10–20 %)	Sensitive	2.0	2.5	3.0
	Semi-tolerant	4.0	6.0	8.0
	Tolerant	6.0	8.0	10.0
Coarse soil (<10 %)	Sensitive	-	3.0	3.0
	Semi-tolerant	6.0	7.5	9.0
	Tolerant	8.0	10.0	12.5

Source: Minhas and Gupta (1992)

Criteria and Standards for Assessing Suitability of Saline Water for Irrigation

According to Ayers and Westcot (1985), waters of greater than 3 dS/m in EC are severely restricted in their use for irrigation. However, waters of many different compositions ranging in salinity up to at least 8 dS/m are being used productively for irrigation in numerous places throughout the world under widely varying conditions of soil, climate, irrigation and cropping. This is evidence of the fact that the actual suitability of given water for irrigation greatly depends on the relative need and economic benefit that can be derived from irrigation with the saline water compared to other alternatives and on the specific conditions of use. Important conditions of use include the crop being grown, various soil properties, irrigation management practices, climatic conditions, and certain cropping and soil management practices. The suitability of water for irrigation should be evaluated on the basis of criteria indicative of its potential to create soil conditions hazardous to crop growth. Relevant criteria for judging irrigation water quality in terms of potential hazards to crop growth are primarily given below (Rhoades et al., 1992):

- **Salinity:** The general effect of salts on crop transpiration and growth are thought to be largely osmotic in nature and, hence, related to total salt concentration rather than to the individual concentrations of specific salt constituents. These effects are generally evidenced by reduced transpiration and proportionally retarded growth, producing smaller plants with fewer and smaller leaves.

Classification of Saline Waters

The suitability of saline water for irrigation is so dependent upon the conditions of use, including crop, climate, soil, irrigation method and management practices, water quality classifications are not advised for assessing water suitability for irrigation. However, for the purpose of identifying the levels of water salinities for which these guidelines are intended, it is useful to give a classification scheme. Such a classification of saline waters is given in Table 4 (Rhoades et al., 1992) in terms of total salt concentration.

Table 4: Classification of saline waters

Water class	Electrical conductivity dS/m	Salt concentration mg/l	Type of water
Non-saline	<0.7	<500	Drinking and irrigation water
Slightly saline	0.7 - 2	500-1500	Irrigation water
Moderately saline	2- 10	1500-7000	Primary drainage water and groundwater
Highly saline	10 - 25	7000-15000	Secondary drainage water and groundwater
Very highly saline	25 - 45	15000-35000	Very saline groundwater
Brine	>45	>35000	Seawater

Strategies to use saline water in irrigation for agriculture

A comprehensive review of the past work strategies to the use of saline water in agriculture is presented here:

Pal et al. (1984) conducted experiment during the winter seasons of 1979-80 and 1980-81 on a sandy loam soil in the semi-desert tract, the accumulation of salts was found to be highest in March after harvest of the barley crop grown with saline water of EC values ranging from 2.2 to 24 mmhos/cm. Highly significant correlations, at the post irrigated period between EC of saturation extract of soils and EC of waters and SAR of saturation extract of soils and SAR of waters have been observed. Table 5 presented the grain and straw yield of barley with respect to different electrical conductivity of irrigation water (EC_{iw}). Barley could be grown economically with irrigation water upto EC 16 mmhos/cm; however an average reduction in grain yield or not more than 43.5% compared to the yield under irrigation with tube well water of EC 2.2 mmhos/cm was obtained.

Table 5: Grain and straw yield of barley with respect to different EC_{iw}

EC_{iw} (mmhos/cm)	1979-80		1980-81	
	Grain yield (q/ha)	Straw yield (q/ha)	Grain yield (q/ha)	Straw yield (q/ha)
2.2	32.10	42.98	30.95	41.95
4	27.98	34.90	26.95	34.20
8	24.78	31.88	23.87	31.72
12	21.73	28.57	21.17	28.15
16	17.86	23.99	17.71	23.60
20	12.75	17.97	12.55	17.18
24	7.18	9.49	7.06	9.10

Boumans et al. (1988) conducted a field survey made during the period 1983-1985 showed that extensive use (104000 shallow tubewells pumping 106000 hectare-metres of water per year) is being made (since about 1975) of shallow-saline groundwater of EC up to 8 dS/m for irrigation in nine districts of Haryana State, India. In four of the districts, the saline water is solely used for irrigation, while in the remaining five it is used either after it is blended with fresh canal water or in alternation with the canal water. Mean rainfall in these areas ranges between 300 and 1100 mm. The soils are dominantly sandy loam in texture. Shallow water tables exist and surface flooding occurs following the monsoons. Table 6 presents the yield reductions found in a survey of the districts for the dominant crops when irrigated solely with the tubewell waters of the indicated levels of salinity. Only a few wells had EC values exceeding 7 dS/m, hence it appears that this level is about the maximum that the farmers have found to be acceptable for long-term use. Yield depressions of 30-40 percent are apparently acceptable to these farmers. The farming practices being used were not given, so it is not possible to evaluate whether opportunities may exist to improve yields through the adoption of modified practices. Still it is obvious that saline waters have been used successfully, even as the sole supply, for irrigation in these districts of India. Their use could be better facilitated by blending or alternating with freshwater supplies.

Table 6: Representative yields (in %) by crop and irrigation water salinity in survey of Hisar area of Haryana, India

Crop	Tubewell salinity, EC in dS/m		
	2-4	4-6	6-8
Cotton	100	70	55
Millet	100	79	52
Wheat	100	89	60
Mustard	100	86	67
Average	100	81	59

Haman (1997) studied the different strategies of salinity control which comes arising in the arid and semi-arid region. In saline conditions, soil water availability to the crop can be accomplished through several strategies such as; leaching salts from the root zone: selecting more salt tolerant crops etc.

Leaching salts from the root zone

In arid climates, irrigation must supply to water requirements of the crop for the growing season. Additional water must be applied to remove the salts from the root zone in order to avoid a build-up of salts which will exceed the threshold level for a given crop and result in yield reduction. The amount of additional water is usually expressed as a leaching fraction which is a dimensionless number. The leaching requirement for sprinkler and surface irrigation can be expressed by equation.

$$LF = D_d/D_i = EC_i/EC_d$$

Where; LF -leaching fraction (dimensionless)

D_d -depth of water drained (inches or mm)

D_i - depth of water applied through irrigation (inches or mm)

EC_i - electrical conductivity of irrigation water (mmho/cm or dS/m)

EC_d -electrical conductivity of drainage water (mmho/cm or dS/m)

Salt tolerant crop

Various crops show different sensitivities to different salinity levels. Some crops are much more tolerant than others. Plants are generally divided into four salinity rating groups: sensitive, moderately sensitive, moderately tolerant, and tolerant (Table 7). Table 8 represents the list of crops under different sensitivity.

Table 7: Threshold and zero yield salinity levels for four salinity groups

Salinity Rating	Threshold Salinity (dS/m)	Zero Yield Level (dS/m)
Sensitive	1.4	8.0
Moderately Sensitive	3.0	16.0
Moderately Tolerant	6.0	24.0
Tolerant	10.0	32.0

(Source: adopted from Jensen, 1980)

Table 8: Example of crops in four salinity rating groups

Sensitive	Moderately Sensitive	Moderately Tolerant	Tolerant
Almond	Alfalfa	Red beet	Sugar beet
Apple	Broccoli	Safflower	Cotton
Avocado	Cabbage	Olive	Date palm
Bean	Tomato	Soybean	Bermuda grass
Carrot	Lettuce	Wheat	
Grapefruit	Corn	Ryegrass	
Orange	Cucumber	Wheatgrass	
Lemon	Grape	Wild rye	
Okra	Peanut		
Onion	Potato		
Strawberry	Radish		
Peach	Rice		
Plum	Sugarcane		

(Source: adopted from Jensen, 1980)

Sharma and Rao (1998) observed 4.2%, 9.7%, 16.3% and 22.2% wheat yield reduction at different EC_{iw} as 6, 9, 12 and 18.8 dS/m, respectively. The high salinity and sodicity of the drainage water increased the salinity and sodicity in the soil profile during the winter season, but these hazards were eliminated by the subsurface drainage during the next monsoon periods. The results indicated that saline drainage water of varying salinity levels can be successfully utilized for the irrigation of winter wheat without any serious soil degradation. Table 9 represented the grain yield (Mg/ha) of wheat as affected by different salinity levels of blended drainage water used for post-sowing irrigations.

Table 9: Grain yield (Mg/ha) of wheat as affected by different salinity levels of blended drainage water used for post-sowing irrigations

EC_{iw} (dS/m)	1986-87	1987-88	1988-89	1989-90	1990-91	1991-92	1992-93
0.5 (CW)	5.40	5.62	6.55	6.52	6.02	5.88	5.89
6	5.36	5.27	6.18	6.12	6.00	5.57	5.81
9	5.48	4.78	5.70	5.82	5.70	5.04	5.90
12	5.28	4.22	5.29	5.32	5.50	4.55	5.72
18.8 (DW)	5.38	3.46	5.00	4.75	5.20	4.28	5.82

Flagella et al. (2004) evaluated the changes in oil yield and fatty acid composition in a high oleic hybrid submitted to different salinity levels of irrigation water. A pot experiment was carried out in a greenhouse with a high oleic sunflower hybrid grown on a loam soil with five salinity levels of irrigation water (0.6, 3, 6, 9 and 12 dS/m). Oil yield showed a significant decrease from 38.3 to 3.4 g per head on increasing salt stress. Under our experimental conditions with a medium textured soil, this result confirms the importance of leaching to limit salt accumulation along the soil profile. Concerning fatty acid oil composition, under all the adopted experimental conditions, both oleic and linoleic acid accounted together for 90% of total fatty acid concentration, while stearic and palmitic acid were about 4%. No great differences were observed in fatty acid composition between the two irrigation regimes. With the higher irrigation volume, only a slight decrease in linoleic and gadoleic acid, whereas an increase in arachidic acid was observed. The only significant differences among saline treatments were observed for oleic and linoleic acid. Oleic acid showed an increase from 82.8% in the control to 86.8% at the highest salinity treatment. Inversely, for linoleic acid a progressive decrease from 6.9 to 2.8% with increasing salinity level was observed. The results indicated that saline water of varying salinity levels can be successfully utilized for the irrigation and soil salinity of these soils can be managed satisfactorily for sustained crop yields.

Malash et al. (2005) evaluated the effect of two water management strategies i.e. alternate and mixed supply of fresh [canal water (0.55 dS/m)] and saline [drainage water (4.2–4.8 dS/m)] water in six ratios (i.e. 100:0, 80:20, 60:40, 40:60, 20:80 and 0:100) through drip and furrow method on tomato yield and salt concentration in the root zone were investigated in the Nile Delta, Egypt. Drip irrigation enhanced tomato growth more, early in the growing season, than did furrow irrigation, but at later stages, there was little difference between the two irrigation systems. Drip irrigation, however, gave higher yield, whereas moderate saline irrigation waters in mixed practice gave the highest values of yield and growth. Thus, the highest yield obtained (3.196 kg/plant) was the result of the combination of drip system and mixed management practice using a ratio of 60% fresh water with 40% saline water.

Wan et al. (2007) investigated the effect of saline water on tomato yield and water use under mulched drip irrigation in North China Plain in 2003, 2004 and 2005. Five treatments of irrigation water with average salinity levels of 1.1, 2.2, 2.9, 3.5 and 4.2 dS/m in 2003 and 2004, and 1.1, 2.2, 3.5, 4.2 and 4.9 dS/m in 2005 were designed. Throughout tomato growing season, the soil matric potentials at 0.2 m depth immediately under drip emitters of all treatments were kept higher than -20 kPa and saline water was applied about 30 days after transplant. Results showed that irrigation water salinity ranging 1.1–4.9 dS/m had few effects on tomato yield, but had some effects on tomato seasonal accumulative water use, water use efficiency (WUE) and irrigation water use efficiency (IWUE). With the increase of irrigation water salinity, WUE (Fig. 1) and IWUE (Fig. 2) increased. After 3 year irrigating with saline water, soil salinity in the 0-90 cm soil depths did not increase. So in North China Plain, or similar semi-humid area, when there were not enough fresh water for irrigation, saline water with salinity from 2.2 to 4.9 dS/m can be applied to irrigate field culture tomatoes after appropriate management strategies were adopted.

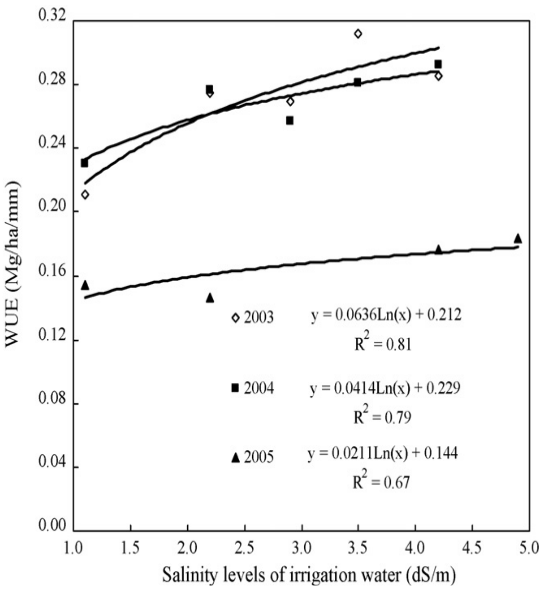

Fig. 1: Relationship between tomato WUE and different salinity levels of irrigation water in 2003, 2004 and 2005

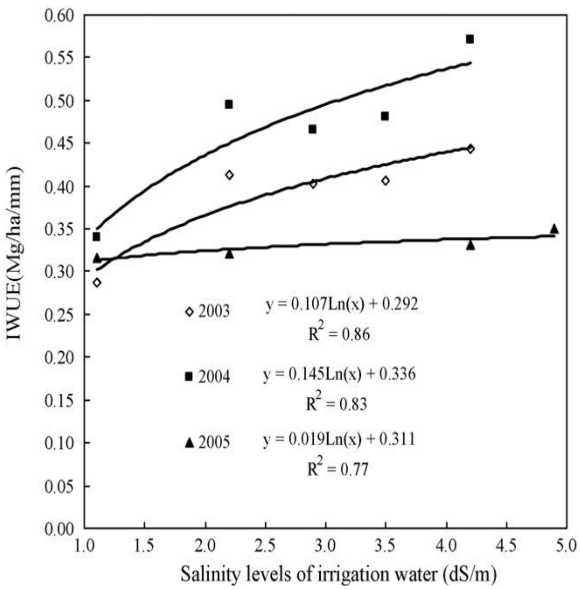

Fig. 2: Relationship between tomato IWUE and different salinity levels of irrigation water in 2003, 2004 and 2005

Wan et al. (2010) carried out the possibility of using saline water for supplement irrigation of cucumber in North China. Saline water was applied via mulched drip irrigation. The average electrical conductivity of irrigation water (EC_{iw}) was 1.1, 2.2, 2.9, 3.5 and 4.2 dS/m in 2003 and 2004, and 1.1, 2.2, 3.5, 4.2 and 4.9 dS/m in 2005. Throughout cucumber-growing season, the soil matric potential at 0.2 m depth immediately under drip emitter was kept higher than -20 kPa and saline water was applied after cucumber seedling stage. Results revealed that cucumber fruit number per plant and yield decreased by 5.7% per unit increase in EC_{iw}. The maximum yield loss was around 25% for EC_{iw} of 4.9 dS/m, compared with 1.1 dS/m. So in North China, or similar semi-humid area, when there is no enough fresh water for irrigation, saline water up to 4.9 dS/m can be used to irrigate field culture cucumbers at the expense of some yield loss.

Singh and Panda (2012) conducted a field experiment at Shahpur village, Hisar, Haryana, India, to study the effect of different qualities of irrigation water on mustard (Brassica juncea, cv. RH-d). Treatments were planned with good quality canal water (EC 0.4 ds/m) and saline groundwater (electrical conductivity (EC) 7.48 dS/m) applied either alone, as blends or in alternate applications. The highest seed and straw yield was recorded in T_1, whereas, in T_3 and T_4. No significant difference was observed but it was higher than T_2 treatment. During the seasons 1997-98 and 1998-99, on comparative with T_1 treatment, while straw yields were recorded 91 and 92%, and 90 and 92% of T_1, for the corresponding periods, seed yields were recorded as 93 and 95% in T_3 and 91 and 92% of T_4 treatments. The WUE with respect to both seed yield (WUE_{seed}) and straw yield (WUE_{straw}), decreased with the decrease in yields and found maximum in T_1 and minimum in T_2. In all treatments, canal water was used for pre-sowing irrigation. In mustard cultivation, saline groundwater with an EC of 7.48 dS m^{-1} can be used safely to supplement all post-sowing irrigations with marginal decline in crop yield. Irrigation with saline groundwater gave a yield as high as 95% of the optimum crop yield obtained with fresh canal water. Thus saline groundwater is a good water source to exploit for supplemental irrigation.

Anonymous (2017-18) evaluated the characterization of cultivated and wild species of tomato at salinity level. Initially two irrigations were given with best available water and after that alternate irrigation was given with saline water according to treatments. Soil samples were taken at monthly intervals for monitoring of salinity. The flowering was late at higher salinity. Results showed that number of fruits per plant was reduced with increase in salinity and this reduction was 31.95, 47.61 and 63.51% at EC 4-6, 6-8 and >8 dS/m, respectively. The percent yield reduction was 31.27, 49.47 and 63.97% at EC 4-6, 6-8 and >8 dS/m, respectively. The results indicated that saline water of varying salinity levels can be utilized for the irrigation with much yield loss.

CONCLUSION

From research papers related to the use of saline water in irrigation for agriculture, it was found that the conjunctive use of saline water (SW) and fresh water (FW) is best for crop production. Conjunctive use of water also increased the irrigation water use efficiency (IWUE) with a little reduction in crop yield compared to constant use of saline water for irrigation. In addition to conjunctive use, salt tolerant verities should be adopted to minimize the effect of salinity and to get the better result in saline medium.

REFERENCES

Anonymous (2017-18). Annual report. *ICAR-Central Soil Salinity Research Institute*, Karnal.

Ayers, R.S., & Westcot, D.W. (1985). Water quality for agriculture. *Irrigation and Drainage Paper* 29, Rev. *1, FAO*, Rome, 174.

Boumans, J. H., Van Hoorn, J. W., Kruseman, G. P., & Tanwar, B. S. (1988). Water table control, reuse and disposal of drainage water in Haryana. *Agricultural Water Management*, *14*(1-4), 537-545.

Cai, X., & Rosegrant, M. W. (2003). 10 World Water Productivity: Current Situation and Future Options. *Water productivity in agriculture: Limits and opportunities for improvement*, *1*, 163.

Chen, Y., Li, X., & Wang, J. (2011). Changes and effecting factors of grain production in China. *Chinese Geographical Science*, *21*(6), 676-684.

Dagar, J. C., & Minhas, P. S. (2016). Saline irrigation for productive agroforestry systems. In *Agroforestry for the Management of Waterlogged Saline Soils and Poor-Quality Waters*, 145-161. Springer, New Delhi.

Devojee, B., Nagababu, G., Kumar, M. M., Nandini, Y., & Hemakumar, H. V. (2018). Assessment and Mapping of Irrigation Water Quality Index of Bapatla Mandal, Guntur District, Andhra Pradesh, India. *Int. J. Curr. Microbiol. App. Sci*, *7*(1), 1914-1920.

Flagella, Z., Giuliani, M. M., Rotunno, T., Di Caterina, R., & De Caro, A. (2004). Effect of saline water on oil yield and quality of a high oleic sunflower (Helianthus annuus L.) hybrid. *European Journal of Agronomy*, *21*(2), 267-272.

Gupta, D., Gulati, I. J., Yadav, N. S., & Singh, A. K. (2017). Response of Isabgol (Plantago ovata) to Bioregulators and Varying Water Salinity Levels Under Drip Irrigation. *Journal of Soil Salinity and Water Quality*, *9*(2), 194-199.

http://www.cssri.org/index.php?option=com_content&view=article&id=77&Itemid=77.

Haman, D. Z. (1997). Irrigating With High Salinity Water. University of Florida, IFAS, Florida.

Jensen, M.E. (1980). Design and Operation of Farm Irrigation Systems. An *ASAE Monograph. American Society of Agricultural Engineers*, 2950 Niles Road, St. Joseph, MI 49085.

Kandiah, A. (1998). Strategies to minimize adverse environmental impacts of saline water use in agriculture. In *Proceedings of the international workshop on use of saline and brackish water for irrigation-10th Afro-Asian co waters. Plant Soil*, *89*, 273-284.

Malash, N., Flowers, T. J., & Ragab, R. (2005). Effect of irrigation systems and water management practices using saline and non-saline water on tomato production. *Agricultural Water Management*, *78*(1-2), 25-38.

Manchanda, H. R. (1976). *Quality of groundwater of Haryana*. Haryana Agriculture University.

Minhas, P. S., & Gupta, R. K. (1992). *Quality of irrigation water: assessment and management. Indian Council of Agricultural Research.*

Minhas, P. S. (1996). Saline water management for irrigation in India. *Agricultural water management*, *30*(1), 1-24.

Minhas, P. S. (1998). Use of poor quality of waters. In: Singh GB, Sharma BR (eds) 50 years of natural resource management. *ICAR*, New Delhi, 327–346.

Pal, B., Singh, C., & Singh, H. (1984). Barley yield under saline water cultivation. *Plant and soil*, *81*(2), 221-228.

Ragab R (1998) The use of saline/brackish water for irrigation: possibilities and constraints. *In Proceedings international workshop on the use of saline and brackish waters for irrigation-implications for the management of irrigation, drainage and crops, 10th Afro-Asian conference. Bali*, 12–41.

Rhoades, J. D., Kandiah, A., & Mashali, A. M. (1992). The use of saline waters for crop production. *Food And Agriculture Organization Of The United Nations,* Rome.

Sharma, D. P., & Rao, K. V. G. K. (1998). Strategy for long term use of saline drainage water for irrigation in semi-arid regions. *Soil and Tillage Research*, *48*(4), 287-295.

Shahid, M., Singh, A. P., Bhandari, D. K., & Ahmad, I. (2008). Groundwater quality appraisal and categorization in Julana block of Jind district, Haryana. *Journal of the Indian Society of Soil Science*, *56*(1), 123-125.

Shahinasi, E., & Kashuta, V. (2008). Irrigation water quality and its effects upon soil. *Tirana Agricultural University, Tirana, Albania BALWOIS*.

Singh, A., & Panda, S. N. (2012). Effect of saline irrigation water on mustard (Brassica Juncea) crop yield and soil salinity in a semi-arid area of North India. *Experimental Agriculture*, *48*(1), 99-110.

Tanwar, B. S., & Kruseman, G. P. (1985). Saline groundwater management in Haryana state, India. In *18th Congress of the International Association of Hydrogeologists,* 24-30.

Wan, S., Kang, Y., Wang, D., Liu, S. P., & Feng, L. P. (2007). Effect of drip irrigation with saline water on tomato (*Lycopersicon esculentum* Mill) yield and water use in semi-humid area. *Agricultural water management*, *90*(1-2), 63-74.

Wan, S., Kang, Y., Wang, D., & Liu, S. P. (2010). Effect of saline water on cucumber (Cucumis sativus L.) yield and water use under drip irrigation in North China. *Agricultural Water Management*, *98*(1), 105-113.