Short Communication

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Quality of underground irrigation water of Bikaner district of Rajasthan

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The soils of arid region are very poor in macro and micronutrients as well as physical properties of soil. The proper soil depth, hard layer/pan are also a problem in some parts for better orchard establishment. The soils of the north-western arid region is known as 'desert soils' and 'grey brown soils' comes in the order of Aridisols which is light textured. The soils often have high salinity. The ground water resource is not only inadequate due to poor surface and sub-surface drainage but is also saline in nature. The irrigation water resources in the region are seasonal rivers and rivulets, surface wells and some runoff water storage devices *(e.g. nadi, tanka, khadins*) and canal irrigation in arid region. Thus, the water resources in arid region are inadequate and can irrigate only just 4% of the area. The annual average rainfall in arid region is very low, varies from 100 mm in north-western sector of Jaisalmer to 450 mm in the eastern boundary or arid zone of Rajasthan. Most of the rainfall occurs during July-September in about 19-21 rain spells. Due to low and unpredictable rainfall pattern in arid region, suitable technology is required to increase productivity. Water is precious input in hot arid region of the country therefore, adoption of micro-irrigation system is advantageous to save water and enhance productivity. For arid environment, the variety is needed which are resistant to biotic and abiotic stresses for sustainable production.

Saline or alkali waters constitute an important source of irrigation for agricultural production in water scares of arid region. Soil salinity and alkalinity problems in Rajasthan are primarily due to irrigation of crops with poor quality waters which are further accentuated by the aridity of the state. Ground water in Rajasthan has diversity of quality problems (Lal *et al.*, 1998). As regards the distribution of quality of under-ground water in the Rajasthan state, only 16% is good, 16% is marginal and rest 68% underground water is poor quality. Further, under poor quality water category, distribution of saline, sodic and saline sodic waters are about 16, 35 and 49%, respectively (Yadav and Kumar, 1995). Unavailability of good quality water for irrigation purposes has deteriorated the soil properties, reduced crop yields and qualities. Low rainfall and poor quality Rajasthan state has developed several water projects for drinking and irrigation purposes since ancient. Several times water projects fail to supply water for irrigation in field crops due to low rainfall, high evaporation losses, over irrigation and higher infiltration rate of soil. In these situations, farmers use underground poor quality water for irrigation resulting in salt accumulation on surface soil resulting in deterioration of soil conditions and consequently low crop-yields. Development of salinity, sodicity and toxicity problems of salts in soils not only reduces crop productivity, quality and limited scope of the choice of the crops. In addition, in dry-hot areas, the availability of good quality water is very limited by low rainfall and high evapotranspiration (El Mahmoudi *et al.*, 2011) and is exacerbated under current global climate change, with severe weather events accompanied by long dry periods (Sietz *et al.,* 2015). The increasing of the population needs more and more food, but at the same time, the consequences of global climate change are compromising crops production (Lesk *et al.*, 2016). In order to reach reasonable and stable crop yields, irrigation can be vital. The agriculture sector is the largest consumer of water, especially in the arid and semi-arid regions, where irrigation water represents from 50% up to almost 90% of total used water (FAO, 2017). Irrigation systems with advanced technologies along with good practices can increase irrigation effectiveness and decrease the water wastage (Levidow, 2014; Tromboni, 2014 and Bortolini, 2016). Appraisal of irrigation water quality based on only a few vital parameters, which consider the crop species to be irrigated and the type of irrigation system and management adopted, can be an easy and flexible method for maximizing the reuse of low-quality water for agricultural purposes (Bortolini *et al.*, 2018). The detailed in sequence is lacking as regard of quality of underground waters of areas of Badrasar district of Bikaner. Therefore, it is very indispensable to categorize the underground waters use for irrigation with respect to their fittingness for crops and soils.

The study was carried out in areas of Badrasar district of Bikaner situated in North-western of part of Rajasthan state of India. Soil of the district falls under category of course grain sandy soils of arid region. The colour of soils ranges from grayish brown to brown and textures of soil are sandy and sandy loam in texture (Dhir and Singh, 1985). The climate of this area is arid type. Erratic rainfall (100-420 mm/year), high evapo-transpiration (1500-2000 mm/year) and poor soil physical and fertility conditions is found in the arid region. Pearl millet, groundnut, cluster bean, sesame, green gram are grown in kharif and mustard, wheat and chickpea crops are dominant crops in *rabi* season. The major sources of irrigation are canals, seepage water from canal in dug well, tubewell, bore wells, pond, *etc*.

Representative ground water samples were collected from areas of Badrasar district of Bikaner situated in North-western part of Rajasthan state of India and analyzed for pH, EC, cationic and anionic composition according to methods as outlined by Richards (1954). Sulphate was determined by using Chesnin and Yien's (1950) method. Water table was measured by using portable water level meter. Ground waters were categorized on the basis of availability of EC, SAR, and RSC values as suggested by Gupta *et al.* (1994). Soil pH, electrical conductivity and sodium adsorption ratio of soil samples were determined as per U.S.D.A. Hand book 60 (Richards, 1954).

Sodium adsorption ratio (SAR):

Residual sodium carbonate: It was calculated from the analysis data for carbonates, bicarbonates and Ca plus Mg as follows (all expressed in me/litre):

RSC (me/litre)= $(CO_3^{2-} + HCO_3^{-}) - (Ca^{2+} + Mg^{2+})$

Maximum concentration of Na^+, K^+, Ca^{++}, Mg^{++}, CO_3^{--}, HCO_3^-, Cl^- and SO_4^{--} was 101.10, 0.13 14.44, 20.03, 1.74, 51.02, 74.09, 4.50, 21.94 0.13, 2.64, 2.97, 1.74, 5.24, 20.33 and 4.50 me L^{-1} and minimum concentration was 11.67, 0.09, 0.77, 1.40, 0.82, 2.78, 8.17, and 2.01 me L^{-1} with mean value 24.45, 0.12, 2.87, 4.00, 1.86, 9.13, 18.18 and 3.30, respetively. The sources of major cations, such as Ca^{2+} and Mg^{2+}, in groundwater can be the weathering of calcium and magnesium minerals (Kumar *et al*., 2009). In the areas of increased clay rich soil dispersed and where Na^+ concentration is higher (Yousaf *et al*., 1987), the Mg^{2+} concentration is relatively higher than that of Ca^{2+}. The ratio HCO_3^-: Na^+ can also be used to assess the weathering process (Kumar *et al*., 2009) that occurs in groundwater. When the HCO_3^-: Na^+ ratio is greater than 1, carbonate weathering occurs, while a ratio of $Na^+ /(Na^+ + Cl^-)$ higher than 0.5 had only one samples, suggesting that ion exchange process is very low. On the whole, the groundwater samples have the concentration of Na^+ higher than that of K^+, because of the greater resistance of K^+ to chemical weathering and its adsorption on clay minerals (Rao, 2008). This suggests that when there is lack of rain, the decomposition of organic matter by bacterial organisms in the soil would not provide the appropriate CO_2 to the rock/ water interaction in dry season. The Na concentration in soil layers can influence the scattering of clay particles, the soil water characteristics, soil aggregate stability, and the formation of soil crusts. Dispersion of soil particles may cause clogging of soil pores, which reduces the soil permeability, soil porosity, and soil water conductivity (Bresler, 1970; Greene *et al*., 1988; He *et al*., 2013; He *et al*., 2015; Tedeschi *et al.* 2005).

Sodium hazard index used is the Sodium Adsorption Ratio (SAR) that expresses the comparative activity of sodium ions in the exchange reactions with the soil. This ratio measures the relative concentration of sodium to calcium and Magnesium. SAR of irrigation water was varied from location to location. The classification of irrigation waters with respect to sodic hazard on the basis of SAR is based primarily on the increase of exchangeable sodium and its effect on the physical conditions of soils. On the basis of SAR, irrigation water may be classified into six classes as proposed by Gupta (1986).

S_0	Non sodic waters: (SAR < 5)	Can be used for irrigation on almost all soils for all crops even those sensitive to sodium.
S_1	Normal waters: (SAR 5 - 10)	Can be used for irrigation on almost all soils with little danger of development of harmful levels of exchangeable sodium for growing all crops except sensitive to sodium.
S_2	Low sodic waters: (SAR 10 - 20)	Can be used for crops, which are semi tolerant or tolerant to sodium on almost all soils such that leaching fraction (LF) is around 0.3. If there is a presence of gypsum or calcium carbonate in soil, these waters can be used more successfully.
S_3	Medium sodic waters: (SAR 20 - 30)	Can be used only for crops which are tolerant to sodium on soils provided with good drainage such that leaching fraction is always greater than 0.3.
S_4	High sodic waters: (SAR 30 - 40)	These waters are directly not suitable for irrigation but may be used in cycle or conjunction with low sodicity waters or with the use of amendments such as gypsum.
S_5	Very high sodic waters: (SAR >40)	These waters are directly not suitable for irrigation without drastic treatment.

Alkali hazard (RSC)

The carbonate or bicarbonate (alkali) hazard on the basis of RSC is primarily based on the precipitation of calcium and/or magnesium and pairing of residual carbonate (CO_3^{--}) or bicarbonate (HCO_3^-) with sodium and formation of sodium carbonate (Na_2CO_3) in the soil and increasing SAR/ESP characterizing it as alkali soil. RSC should be calculated for high pH (> 8.5) waters. On the basis of RSC, irrigation waters may be classified into six classes as proposed by Gupta (1986).

Based on above said classification (Fig. 2), 50% of irrigation water was low alkali waters (RSC < 2.5 me L^{-1}) followed by 31.25 % medium alkali waters (RSC 2.5 - 5.0 me L^{-1}), 12.50% high alkali waters (RSC 50-10 me L^{-1}) and 6.25 % high alkali waters (RSC >10.0 me L^{-1}). The relative abundance of sodium with respect to alkaline earths, and the quantity of bicarbonate and carbonate in excess of alkaline earths also influence the suitability of water for irrigation. This excess is denoted by 'Residual sodium carbonate' (RSC). A negative RSC value indicates that the total concentration of

A_0	Non-alkali waters: (RSC Negative)	Can be used for irrigation on almost all soils for all crops for indefinitely long periods without any problem.
A_1	Normal waters: (RSC 0 me L^{-1})	can be used for irrigation o n almost all soils for all crops even those are sensitive to carbonates or bicarbonates
A_2	Low alkali waters: (RSC < 2.5 me L^{-1})	Can be used for irrigation on almost all soils for all crops.
A_3	Medium alkali waters: (RSC 2.5 - 5.0 me L^{-1})	Can be used for irrigation on almost all soils with little danger of the development of harmful levels of alkali conditions for growing all crops except sensitive to carbonates or bicarbonates.
A_4	High alkali waters: (RSC 5.0 - 10.0 me L^{-1})	Can be used for irrigation on soils provided with good drainage such that leaching fraction is not less than 0.3 for growing semi -tolerant and tolerant crops to sodium. EC should be < 3.0 dS m^{-1} and SAR should be <10.0
A_5	Very high alkali waters: (RSC > 10.0 me L^{-1})	These waters are directly not suitable for irrigation but may be used in conjunction with low alkalinity waters or with the use of amendments.

CO_3^{2-} and HCO_3^- is lower than the sum of the Ca^{2+} and Mg^{2+} concentrations, reflecting that there is no residual carbonate to react with Na^+ to increase the Na hazard in the soil. Trace metals including Cu^{2+}, Zn^{2+}, Fe^{3+}, As^{3+}, Mn^{2+} were concentrations were low and considered to be suitable for crop production and the soil environment (Ayers and Westcot, 1985). There are situations where canal good quality water is available for irrigation but not in adequate quantities to meet the evapotranspirational needs of crops. Under these conditions, the strategies for obtaining maximum crop production could include mixing of high salinity water with good quality water to obtain irrigation water of medium salinity for use throughout the cropping season. Alternatively, good quality water might be used for irrigation at the more critical stages of growth, *e.g.* germination, and therefore the saline water at the stages where the crop has relatively more tolerance. Further research is needed to define the best options considering the tolerance of crops at different growth stages, critical stages of growth *vis-a-vis* soil salinity, etc (Bortolini *et al.,* 2018).

Problematic soil in semi arid region is formed because of indiscriminate application of irrigation with poor quality under-ground water. The water falling under good quality category can be used safely for groundnut, wheat and leguminous crops whereas water which is marginally saline can be used for pearl millet and mustard crops in area having coarse textured soil. Ground water rated as marginally alkali can be used effectively with gypsum application for mustard and barley. The water rated as saline, alkali and highly alkali soils are unfit for irrigation and their indiscriminate use caused secondary salinization and sodication to the extent that growth of the crop may be adversely affected.

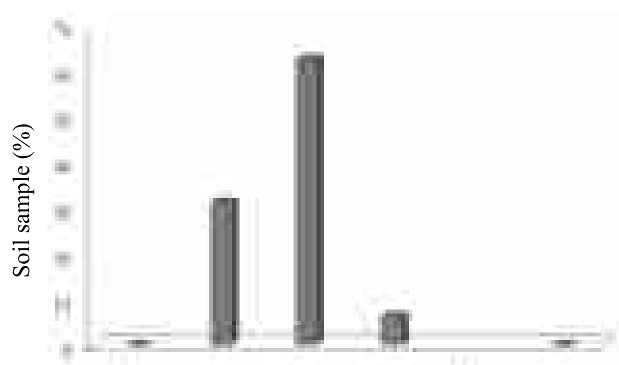

Fig. 1. Classification of irrigation waters with respect to sodic (SAR) hazard on the basis of SAR

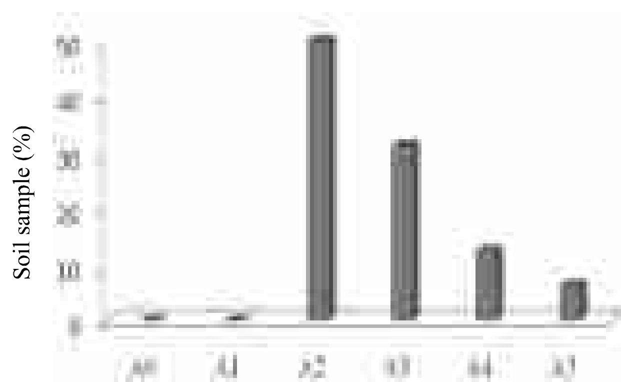

Fig. 2 Classification of irrigation waters with respect to alkali (RSC) hazard on the basis of SAR

Table 1. Quality of underground irrigation water of Badrasar of Bikaner district of Rajasthan

	Cationic conc. (me L^{-1})				Anionic conc. (me L^{-1})			
Badrasar	Na^+	K^+	Ca^{++}	Mg^{++}	CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}
Mean	24.45	0.12	2.87	4.00	1.86	9.13	18.18	3.30
Minimum	11.67	0.09	0.77	1.40	0.82	2.78	8.17	2.01
Maximum	101.10	0.13	14.44	20.03	1.74	51.02	74.09	4.50
Median	19.19	0.12	2.09	2.87	1.23	4.96	13.25	3.25
Standard Deviation	21.09	0.01	3.26	4.47	0.25	11.82	15.54	0.74

Table 2. SAR and RSC of underground irrigation water of Badrasar of Bikaner district of Rajasthan

Badrasar	SAR	RSC
Mean	11.99	4.12
Minimum	9.20	0.12
Maximum	24.35	24.65
Median	10.88	2.60
Standard Deviation	3.71	5.93

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