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2 authors:

Y. P. Singh
Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya (RVSKVV)

Sarwan Kumar Dubey
ICAR-Indian Institute of Soil and Water Conservation (Earlier known as CSWCRTI)

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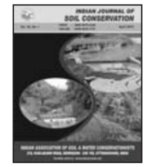

Impact of underground irrigation water on soil properties and sodic soil reclamation technologies on pearlmillet-wheat crop sequence

Y.P. Singh and S.K. Dubey[1]

Rajmata Vijayaraje Scindia Krishi Viswa Vidyalaya, Zonal Agricultural Research Station-Krishi Vigyan Kendra, Morena-476001, Madhya Pradesh; [1]ICAR-Indian Institute of Soil and Water Conservation, Research Centre, Chhalesar, Agra-282006, Uttar Pradesh.
[1]E-mail: skdubeyagra@gmail.com

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ABSTRACT

An on-farm study was undertaken to determine the quality of underground water, its effect on soil properties in the canal command areas, and impact of sodic soil technologies *i.e.* gypsum levels, green manuring, farm yard manure (FYM) and deep tillage on yield of pearlmillet-wheat crop sequence. Eighty six water samples collected from canal command area of Tonk district of Rajasthan revealed that 22.1, 10.9, 5.8, 21.5, 29.8 and 9.9% water samples were under good, marginally saline, saline, marginally alkali, alkali and highly alkali categories, respectively. Most of these waters had dominance of sodium followed by calcium in cations and chloride as major anion followed by bicarbonate and carbonates. After interventions of sodic soil reclamation, wheat crop in *rabi* and pearlmillet in next *kharif* season was grown. Maximum mean yields of 2.53 t ha^{-1} grain and 11.0 t ha^{-1} straw of pearlmillet and 3.95 t ha^{-1} grain and 4.74 t ha^{-1} straw of wheat were obtained with deep tillage in summer along with gypsum application @ 50% GR, green manuring and FYM @ 10 t ha^{-1} followed by GR-50% along with green manuring and FYM @ 10 t ha^{-1}. Treatment of deep tillage in summer along with GR-50%, green manuring and FYM @ 10 t ha^{-1} resulted in significant reduction of EC, pH, ESP and bulk density, improvement in infiltration rate and availability of N, P, K and micronutrients.

1. INTRODUCTION

Soil salinity and alkalinity problems in Rajasthan occur primarily due to irrigation with poor quality waters which are further accentuated by the aridity of state. Indiscriminate use of such water can often lead to crop failures and to the development of saline or sodic soils which, in turn, require expensive treatment to make them productive again (Jha *et al.,* 2012). Majority of ground water in Rajasthan is of poor quality. As regards the distribution of water quality in Rajasthan state, only 16% groundwater has good quality, 16% marginal and 68% underground water is of poor quality (Yadav and Kumar, 1995). According to Yadav and Kumar (1995), distribution of saline, sodic and saline sodic waters is about 16, 35 and 49%, respectively, under poor quality water category. Salt affected soils are an important ecological entity in India and around 8.6 M ha area is affected in different climatic regions. Of this, 1.122 m ha area (Singh, 1992) is in Rajasthan alone where soil reclamation programme is less effective as poor quality ground-water is either the major or the only source of irrigation. Due to unavailability of good quality water, use of poor quality under-ground water for irrigation has deteriorated the soil properties and reduced crop yields. Rajasthan state has developed several water projects for irrigation and drinking purposes. Galwa, Moti and Mansi dams for rain water conservation were developed in Tonk district. These dams are used to supply irrigation water through canals at critical stages of crops. Sodicity problem in command areas has been created due to indiscriminate use of poor ground water quality for irrigation purpose. The problem is further aggravated due to non-availability of canal water at the scheduled period of irrigation. It calls for management of such soils to improve their physico-chemical condition for attaining higher sustainable crop production in command areas. The present study of farm participatory research was accordingly carried out to study determine the quality of ground water and their effects on soil properties in command area and interventions of levels of gypsum, green manuring, farm yard manure (FYM) and deep tillage on yield of pearl millet wheat crop sequence and physico-chemical properties of a clay loam textured sodic soil.

2. MATERIALS AND METHODS

The study was carried out in Tonk district situated in North-Eastern part of Rajasthan state of India located at $23^0$3'- $30^0$12' N latitude and $69^0$30'-$78^0$17' E longitude. Ground water samples from 86 tube wells/open wells were collected randomly during 2006 distributed in 42 villages of command area of Tonk district and analyzed for pH, EC, cationic and anionic composition as outlined by Richards (1954). The fluoride content in ground water was determined using specific ion analyzer with F electrode (Orion). Waters were categorized on the basis of electrical conductivity (EC), sodium adsorption ratio (SAR), and residual sodium carbonate (RSC) values as suggested by Gupta *et al.* (1994). Surface soil samples (0 to 0.20 m depth) were also collected from these fields from the command area which are being irrigated with corresponding waters in the absence of canal water supplies. The correlations between soil properties and water characteristics were worked out at 5% significant level. On-farm trials were initiated in Galwa command area of Uniara Panchayat Samiti of Tonk district of Rajasthan. Five representative farmers were selected for on-farm participatory trials. The selected interventions for soil reclamation were as follows: T_1: farmer's practice (control), T_2: gypsum application as per gypsum requirement (GR) 25% + green manuring (GM), T_3: GR-50% + GM, T_4: GR-25% + GM + farm yard manure (FYM) @ 10 t ha^{-1}, T_5: GR-50% + GM + FYM @ 10 t ha^{-1}, T_6: deep tillage (DP) + GR-25% + GM + FYM @ 10 t ha^{-1} and T_7: GR-50% + DP + GM + FYM @ 10 t ha^{-1}. These seven interventions were imposed only in first year from 28th June to 2nd July in five locations in randomized complete block design (RCBD). The experimental crop was wheat in r*abi* season and pearl millet grown in the next *kharif* season. The experimental fields were divided into seven sub-plots, each having 500 m^2 areas with 0.30 m high bunds for rain water conservation. Before making plots, field-leveling and deep tillage up to 24 cm was done by using disc plough during last week of May to first week of June (summer season). *Sesbania* seed was sown after application of gypsum as per treatment. The gypsum requirement varied from 3.75 to 5.46 t ha^{-1} depending on sodicity levels of the soil. Gypsum requirement of experimental field was determined by Schoonover's method (1952). The recommended packages of practices were followed during all the years as given in Table 1. *Sesbania* crop for green manuring was incorporated in to soil by harrowing 50 days after sowing. The total rainfall received during the experimentation period was 451 and 506 mm in 2006-07 and 2007-08, respectively. As per availability of irrigation water from canal, pre irrigation, crown root, tillering and booting stage irrigations were given by canal (good quality) water and only at milking stage, irrigation were given by under-ground (sodic) water during 2006-07, while during 2007-08 irrigation in wheat crop with canal water.

After harvest of wheat crop, soil samples were taken from 0 to 0.20 m soil layer with an auger 4 cm in diameter. The soil samples were air dried and ground to pass through a 2 mm sieve. Particle size analysis was performed according to pipette method (Piper 1942). Soil pH, electrical conductivity (1:2 soil water ratio) and exchangeable sodium of soil samples were determined using pH meter, conductivity bridge and flame photometer, respectively. The exchangeable sodium percentage was determined as per U.S.D.A. Hand book 60 (Richards, 1954). Organic carbon content was determined by wet oxidation method as outlined by Walkley and Black (1934). Available N, P, K and

Table: 1
Details of experimental operations

Operations	Sesbania	Pearlmillet	Wheat
Date of sowing	28th June to 2nd July	5-7th July	15-22 November
Variety	Local	HHB-67	Raj-3765
Line to line spacing (cm)	15	45	22.5
Seed rate (kg ha^{-1})	40	20	100
N application (kg ha^{-1}) through urea	Nil	60	90
P_2O_5 application (kg ha^{-1}) through diammonium phosphate	Nil	60	60
Zn application (kg ha^{-1}) through zinc sulphate	Nil	-	05
Pre-sowing irrigation (70 mm)	First monsoonal rain	First monsoonal rain	1
Post-sowing irrigation (50 mm)	Rainfed	Rainfed	4
Date of harvest	25-29th August*	5-9th October	9-12th April

*ploughing of sesbania (green manuring) by harrowing micronutrients were determined by Kjeltec-II auto analyzer, Olsen P, NH_4OAc-extractable K and DTPA extraction using atomic adsorption spectrophotometer (Jackson, 1973), respectively. Infiltration rate after harvest of wheat from each treatment in each year were measured in situ by double ring infiltrometer method and measurement of soil bulk density using core sampler (0.12 m diameter and 0.15 m length). The selected soil of farmers' field was clay loam in texture and ranges of EC 0.56 to 0.78 dS m^{-1} and pH 8.95 to 9.16. The soils of selected fields were deficient in organic carbon (1.7 to 2.6 g kg^{-1}), available N (151 to 161 kg ha^{-1}), P (7.2 to 8.1 kg ha^{-1}) and Zn (0.45 to 0.57 mg kg^{-1}), but medium in available K (206 to 215 kg ha^{-1}). Available Cu (>0.2 mg kg^{-1}), Fe (>5.0 mg kg^{-1}) and Mn (>2.0 mg kg^{-1}) contents were above the critical limit. Sodic irrigation water used in the study had EC 0.67 dS m^{-1}, RSC 9.0 m.e. L^{-1}, SAR 14.7, while canal water had EC 0.25 dS m^{-1}, RSC 0.80 m.e. L^{-1}, SAR 0.92.

3. RESULTS AND DISCUSSION

Quality of Water and its Effect on Soil

The ground water depths of the wells in the command area varied between 11 to 24 m. The EC, pH, RSC and SAR of underground waters were found to be in the range 0.38 to 8.31 dS m^{-1}, 7.5 to 9.4, 0 to 16.52 m.e. L^{-1} and 0 to 25.47, respectively (Table 2). Dominant cation in these waters was sodium which ranged from 0.16 to 59.69 mmol L^{-1}, while amongst anions chloride was dominant followed by bicarbonate. It was observed that increasing depth of water table increase the concentration of anions and cations in underground water. Out of 86 water samples from command area, 22.1, 10.9, 5.8, 21.5, 29.8 and 9.9% water samples were under good, marginally saline, saline, marginally alkali, alkali and highly alkali categories, respectively as suggested by Gupta *et al*. (1994). Correlation studies revealed that water table was significantly and positively correlated with EC, SAR and RSC of irrigation water (r= 0.619, 0.573 and 0.715). Similarly, significantly positive correlation of water table with fluoride content in underground water (r= 0.598) was also observed.

Surface (0 to 0.20 m depth) soil samples were also collected from the fields irrigated with respective waters and range of their chemical characteristics is given in Table 2. It was observed that EC of almost all the samples is less than 2.78 dS m^{-1} and soil was alkaline in nature having clay loam in texture. Correlation studies of soils of command area showed that EC of soil was significant and positively correlated with EC of irrigation water (r = 0.812). Similarly, SAR of irrigation water and SAR of soil was also positively correlated (r = 0.591). Soil pH was also significantly and positively correlated with sodium (r= 0.552), carbonate (r= 0.675) and bicarbonate (r= 0.699) of underground irrigation water. Lal *et al*. (1998) also recorded similar results in light textured soil.

Table: 2
Characteristics of tube well/open well waters and their effects in soil

Characteristics	Water	Soil
pH	7.5 to 9.4	7.73 to 9.61
EC (dS m^{-1})	0.38 to 8.31	0.26 to 2.78
HCO_3^- (m.e. L^{-1})	0.57 to 24.64	0.56 to 4.75
CO_3^- (m.e. L^{-1})	Nil to 4.87	0.41 to 3.89
Cl- (m.e. L^{-1})	0.18 to 45.69	0.26 to 2.40
SO_4^{2-} (m.e. L^{-1})	0.0 to 4.63	Trace to 0.39
Ca^{2+} (m.e. L^{-1})	0.28 to 18.69	0.62 to 1.16
Mg^{2+} (m.e. L^{-1})	Nil to 4.81	0.18 to 0.75
Na^+ (m.e. L^{-1})	0.16 to 59.69	0.42 to 9.18
K^+ (m.e. L^{-1})	0.02 to 0.24	0.11 to 0.37
F^+ (mg L^{-1})	Nil to 12.0	-
RSC (m.e. L^{-1})	Nil to 16.52	-
SAR	Nil to 25.47	1.06 to 9.64
Sand (%)	-	34 to 41
Silt (%)	-	31 to 42
Clay (%)	-	24 to 28
Soil Texture	-	Clay loam
Water Table (m)	11 to 24	11 to 24

Effect on Yield

For sodic soil reclamation, application of gypsum as per GR @ 25% and 50% alone or in combination with green manuring, FYM @ 10 t ha^{-1} and deep tillage in summer were effective and significantly improved the grain and straw yields of pearlmillet and wheat as compared to control (Table 3). Pooled yield indicated that the treatment of deep tillage in summer + GR-50% + green manuring + FYM @ 10 t ha^{-1} (T_7) was the best treatment and resulted highest mean yields of 2.53 and 11.00 t ha^{-1} of grain and straw, respectively of pearlmillet, while 3.95 and 4.74 t ha^{-1} of grain and straw, respectively, of wheat was recorded followed by treatment T_5. Similar results with deep tillage were also reported by Sinha *et al.,* 2011. The lowest mean yield of 0.94 and 4.44 t ha^{-1} of grain and straw of pearlmillet and 1.19 and 1.74 t ha^{-1} of grain and straw of wheat, respectively was recorded with farmer's practice (T_1). Application of gypsum enhanced the availability of soluble calcium directly and indirectly through dissolution of native $CaCO_3$. The released calcium thus displaced the Na^+ from exchange complex and removal of soluble Na with anions ($CO_3^{=}$ + HCO_3^-) through leaching reduced the pH of soil as well as improved the physico-chemical properties of soil. Similar results were also obtained by Jha *et al.* (2012) in wheat crop irrigated with poor quality waters. Addition of organic manure and farm waste improved the physico-chemical environment in soil and consequently, greater

Table: 3

Response of levels of gypsum, deep tillage, green manuring and FYM on grain and straw yields of pearlmillet and wheat

Treatments	Pearlmillet yield (t ha^{-1})			Wheat yield (t ha^{-1})		
	2007	2008	Mean	2006-07	2007-08	Mean
T_1	1.01 (4.87)*	0.87 (4.01)	0.94 (4.44)	1.27 (1.79)	1.11 (1.68)	1.19 (1.74)
T_2	1.49 (6.57)	1.42 (6.38)	1.46 (6.48)	2.80 (3.01)	2.88 (3.14)	2.84 (3.08)
T_3	1.81 (7.96)	2.05 (8.81)	1.93 (8.39)	3.07 (3.48)	3.33 (3.62)	3.20 (3.55)
T_4	2.01 (9.43)	2.07 (9.35)	2.04 (9.39)	2.89 (3.11)	3.09 (3.53)	2.99 (3.32)
T_5	2.16 (9.95)	2.42 (10.75)	2.29 (10.35)	3.51 (4.36)	3.89 (4.54)	3.70 (4.45)
T_6	2.10 (10.06)	2.17 (10.24)	2.14 (10.15)	3.49 (3.96)	3.43 (3.86)	3.46 (3.91)
T_7	2.39 (10.81)	2.67 (11.18)	2.53 (11.00)	3.78 (4.67)	4.11 (4.80)	3.95 (4.74)
CD at 5%	0.11 (0.36)	0.14 (0.45)	- -		0.34 (0.51)	- -

Figures in parenthesis indicate straw yield. T_1: farmer's practice (control), T_2: gypsum application as per gypsum requirement (GR) 25% + green manuring (GM), T_3: GR-50% + GM, T_4: GR-25% + GM + farm yard manure (FYM) @ 10 t ha^{-1}, T_5: GR-50% + GM + FYM @ 10 t ha^{-1}, T_6: deep tillage (DP) + GR-25% + GM + FYM @ 10 t ha^{-1} and T_7: GR-50% + DP + GM + FYM @ 10 t ha^{-1}

uptake of nutrients by plants from the soil. This is in agreement with the earlier findings (Mohamed, 2012) reported enhanced productivity of rice and wheat by improving physico-chemical properties of sodic soil when amended with gypsum and FYM (10 t ha^{-1}).

Effect on Physico-chemical Properties

Application of gypsum @ 25% or 50% GR alone or in combination with GM, FYM and deep tillage in summer significantly reduced the pH and ESP and increased the available N, P, K and micronutrients (Table 4). Maximum reduction noticed in pH was 1.02, ESP 24, bulk density 0.07 Mg m^{-3}, and increase in organic carbon was 0.3 g kg^{-1} soil, available N 61 kg ha^{-1}, P 8.8 kg ha^{-1}, K 48 kg ha^{-1}, Zn 0.24 mg kg^{-1}, Fe 1.0 mg kg^{-1}, Cu 0.06 mg kg^{-1} and Mn 0.5 mg kg^{-1} with the treatment of deep tillage in summer along with GR-50% + green manuring + FYM @ 10 t ha^{-1}. Next best treatment was T_5 (GR-50% + green manuring + FYM @ 10 t ha^{-1}) where compared to control treatment, reduced in pH was 1.01 and in ESP 22, and increase in organic carbon 0.1 g kg^{-1}, available N 48 kg ha^{-1}, P 7.0 kg ha^{-1}, K 45 kg ha^{-1}, Zn 0.20 mg kg^{-1}, Fe 0.9 mg kg^{-1}, Cu 0.04 mg kg^{-1} and Mn 0.4 mg kg^{-1}. Application of gypsum and organic manures reduced soil sodicity, improved physico-chemical properties and consequently availability of nutrients in soil (Minhas *et al*., 1995). Arora *et al.* (1991) also reported that deep tillage improved the physical properties of soil.

Table: 4

Response of gypsum, deep tillage, green manuring and FYM on physico-chemical properties of surface soil after harvest of wheat (2 years mean)

Treatments	EC (dS m^{-1})	pH	ESP	OC (g kg^{-1})	BD (Mg m^{-3})	IR (cm h^{-1})	Available nutrients						
							N	P (kg ha^{-1})	K	Zn	Fe (mg kg^{-1})	Cu	Mn
T_1	0.65	9.14	38	1.8	1.45	0.61	158	8.5	231	0.55	5.0	0.24	2.2
T_2	0.49	8.36	24	1.7	1.44	1.38	179	12.2	238	0.65	5.2	0.25	2.3
T_3	0.45	8.26	21	1.9	1.43	1.56	187	12.5	254	0.69	5.3	0.26	2.5
T_4	0.44	8.33	19	1.9	1.41	1.61	189	13.6	253	0.72	5.5	0.27	2.6
T_5	0.45	8.13	16	1.9	1.41	1.82	206	15.5	276	0.75	5.9	0.28	2.6
T_6	0.38	8.21	16	2.1	1.39	2.85	209	14.7	271	0.74	5.8	0.28	2.7
T_7	0.39	8.12	14	2.1	1.38	3.15	219	17.3	279	0.79	6.0	0.30	2.7
CD at 5%	0.17	0.31	1.7	NS	0.02	0.51	29	1.7	31	0.07	0.19	0.02	0.17

T_1: farmer's practice (control), T_2: gypsum application as per gypsum requirement (GR) 25% + green manuring (GM), T_3: GR-50% + GM, T_4: GR-25% + GM + farm yard manure (FYM) @ 10 t ha^{-1}, T_5: GR-50% + GM + FYM @ 10 t ha^{-1}, T_6: deep tillage (DP) + GR-25% + GM + FYM @ 10 t ha^{-1} and T_7: GR-50% + DP + GM + FYM @ 10 t ha^{-1}.

Infiltration Rate

At the end of wheat crop during all the years, infiltration rate was measured in all the treatments (Table 4). The infiltration rate significantly increased with the application of gypsum @ 25% or 50% with green manuring only or along with FYM @ 10 t ha^{-1} and deep tillage in summer. Maximum infiltration rate 3.15 cm h^{-1} was recorded with deep tillage in summer + GR-50% + green manuring + FYM @ 10 t ha^{-1} followed by 2.85 cm h^{-1} in the treatment of deep tillage in summer + GR-25% + green manuring + FYM @ 10 t ha^{-1} and 1.82 cm h^{-1} with GR-50% + green manuring and FYM @ 10 t ha^{-1}, respectively. Application of gypsum to sodic soil has been reported to improve aggregate stability and consequently the infiltration rate (Agassi *et al.*, 1981; Dubey and Mondal, 1994).

4. CONCLUSIONS

Salt-affected soils in command areas are created primarily due to indiscriminate irrigation with poor quality under-ground water because several times canal water not available for irrigation. Survey conducted in the study indicated that 22.1, 10.9, 5.8, 21.5, 29.8 and 9.9% underground water samples were under good, marginally saline, saline, marginally alkali, alkali and highly alkali categories, respectively. The grain and straw yields of pearlmillet and wheat in farmers' fields were significantly improved by the addition of gypsum @ 25 and 50% GR with green manuring or along with FYM and deep tillage in summer. An increase in content of organic carbon, available N, P, K and micronutrients, and a decrease in EC, pH, ESP and bulk density of the soils was observed with these interventions. Maximum yields of pearlmillet and wheat was obtained with deep tillage in summer along with gypsum application @ 50% GR of soil + green manuring + FYM @ 10 t ha^{-1} followed by GR-50% of soil + GM + FYM @ 10 t ha^{-1} and deep tillage in summer along with gypsum application @ 25% GR of soil + green manuring + FYM @ 10 t ha^{-1} in canal command areas.

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