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Management of Saline-Sodic Water in Cotton-Wheat Cropping System

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ABSTRACT

A long-term field experiment was conducted for 7 years to evaluate the effect of different amendments to mitigate the adverse effect of saline-sodic water in a calcareous soil under cotton-wheat cropping system. The pooled results over 7 years revealed that the application of saline-sodic water decreased the mean cotton-seed yield by 20.7% as compared to good quality canal water. However, wheat-grain yield was not adversely affected by quality of irrigation water. Among the different amendments, gypsum and farmyard manure were more effective in mitigating the adverse effect of saline-sodic irrigation water. Cotton-seed yield reduction was 9.8% with the addition of farmyard manure and remained only 8.8% with the addition of gypsum as compared to good quality water. However, when saline-sodic water was used alternately with good quality canal water, the recorded cotton-seed yield reduction was only 6.1%. These results suggest that in calcareous soils, farmyard manure is useful in ameliorating long-term deleterious effects of saline sodic irrigation water and sustaining the productivity of cotton-wheat system.

Keywords: Calcareous soil, Farmyard manure, Gypsum, Irrigation water, Semi-arid region, Zinc.

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INTRODUCTION

In different states of India, groundwater survey indicated that quantity of poor quality water being utilized for irrigation ranged from 32-84% of the total groundwater development (Chaudhary, 2003). This problem is particularly acute in north-western India where 40-60% of the groundwater showed high incidence of residual alkalinity (Minhas and Bajwa, 2001). Dwindling supplies of good quality water forced the farmers in the arid and semi-arid regions to use saline-sodic underground water for irrigation of various crops. The use of such type of water for long period of time results in increased pH and Electrical Conductivity (EC), and creates a hostile soil environment, which adversely affects plant growth and causes clay dispersion, followed by clogging of pores due to clay migration (Grattan and Oster, 2003).

In the Indo-Gangetic plains, where the soils are light in texture and underground water is brackish, farmers generally grow cotton in rotation with wheat by applying four to five irrigations to each crop. In this region, the only source of good quality water for irrigation is river water supplied through canals which is available in scarcity. There is great need for judicious use of canal water because excess usage causes deep percolation resulting in high water table and secondary salinization (Boumans *et al.*, 1988; Datta and de Jong, 2002). Judicious use of available canal water with minimal

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deep percolation, and sustainable use of underground saline sodic water is the need of the hour for sustaining the land resources.

In the region, irrigation with poor quality waters usually leads to an increase in soil salinity and sodicity problem and thus causes reduction in crop yields (Choudhary and Ghuman, 2008). Under such situations, it is suggested that for successful use of saline/sodic waters, crops that are semi-tolerant to tolerant (wheat, cotton, mustard) as well as those with low water requirement should be grown (Minhas *et al.*, 2004). The period of emergence and early growth of seedlings is the most critical stage of cotton crop growth, and plants can often tolerate high salinity if good quality water was used for pre-sowing irrigation to leach the salts out of the seeding zone (Boumans *et al.*, 1988). Furthermore, the deleterious effects of poor quality water are less in calcareous soils as sodium (Na) saturation of the soil is retarded due to higher amount of native Calcium Carbonate ($CaCO_3$) (Choudhary *et al.*, 2011). Lal *et al.* (2008) concluded that $CaCO_3$ was one of the major sources that released Calcium (Ca) and bicarbonate ions in the solution when sodic waters are applied. They further reported that using sodic water in alkali soils rich in Ca and Magnesium (Mg) bearing minerals like feldspars and $CaCO_3$ could maintain proportionately higher (Ca+Mg)/Na ratio in the soil solution. Calcium ions (Ca^{2+}) might also be produced from dissolution of silicate minerals (plagioclase feldspars) or $CaCO_3$ of meta-stable form, which is more soluble than pure silicate minerals present in the soil (Curtin *et al.*, 1995). Use of soil amendments is to counter the effect of sodium, by increasing the soluble Ca content or by increasing the salinity of the irrigation water. Gypsum is the most commonly used soil amendment. Since water infiltration problems caused by sodium affect mainly the upper few centimetres of soil, application of gypsum is preferred.

Ahmed *et al.* (2006) reported that smaller amounts of gypsum are required for the reclamation in calcareous soils than for non-calcareous soils. In calcareous soils, organic materials such as farmyard manure are effective in mobilizing Ca^{2+} from inherent and precipitated $CaCO_3$ resulting in improved soil properties, higher organic carbon content and higher yields of rice and wheat crops (Choudhary *et al.*, 2011). However, in the absence of amendments, the application of sodic water to cotton causes zinc deficiency and farmers have to top dress zinc to ameliorate this deficiency. Under poor quality irrigation water conditions, farmers apply zinc and organic and inorganic amendments for sustaining yield of various crops. However, under calcareous soils, the quantity of these amendments required needs to be explored. The present investigation was undertaken to evaluate the effects of zinc, farmyard manure and gypsum alone and in combination to mitigate the adverse effects of saline-sodic water in a cotton-wheat rotation on calcareous soil in a semi-arid region of north western India.

MATERIALS AND METHODS

Experimental Site and Soil

A long-term field experiment was conducted at Punjab Agricultural University Regional Station, Bathinda, India (30° 9' N and 74° 56' E; altitude 211 m asl) for 7 years (2004-2011). The experimental site forms a part of the Indo-Gangetic alluvial plains which were formed with varying pleistocene and recent alluvial deposits of the rivers of Indo-Gangetic system. The site is semi-arid (dry), with mean rainfall of 401 mm. Rainfall is monsoonal in nature, 70-80% is received during the months of July, August and September, which coincides with the active growing season of cotton. The soil of the experimental field belongs to the Gehri Bhagi series (Mixed, hyperthermic, Ustochreptic Camborthid) and has a loamy sand texture. The physical and chemical properties of the experimental soil are presented in Table 1. The organic carbon

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Table1. Physical and chemical characteristics of soil profile of experimental field before start of the experiment during 2004.

Soil depth	pH	EC [a] (dS m^{-1})	Volumetric moisture (%) at 1/3 bar	Volumetric moisture (%) at 15 bar	Available soil water (mm)	Bulk density (g cm^{-3})
0-15	8.47	0.244	24.2	7.4	29	1.51
15-30	8.45	0.236	26.3	8.6	28	1.55
30-60	8.72	0.236	25.8	9.5	51	1.41
60-90	8.56	0.232	27.3	9.6	54	1.43
90-120	8.47	0.236	26.4	9.8	53	1.51
120-150	8.49	0.235	27.1	7.7	57	1.52
150-180	8.43	0.231	26.7	8.5	52	1.54
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[a] Electrical Conductivity measured in 1:2 soil water ratio at the temperature of 25°C.

content of the surface soil layer (0-15 cm) was 0.33% (Nelson and Sommers, 1996) and $CaCO_3$ was 4.87%. The available phosphorus (Olsen *et al.*, 1954) and available potassium (Knudsen *et al.*, 1982) in the surface layer were 13.8 and 317 kg ha^{-1}, respectively. The soil in the experimental field had no salinity or drainage problem and the water table was deeper than 12 m. Thus, the groundwater did not interfere in the root zone.

Experimental Treatments and Procedures

The experiment was laid out in Randomized Complete Blocks Design (RCBD) with 8 treatments and four replications. The treatments were irrigation with good quality Canal Water (CW) (T_1), irrigation with CW along with application of Zinc (Zn), FarmYard Manure (FYM) and Gypsum (Gyp) (T_2), irrigation with CW and Saline-Sodic Water (SSW) alternately (T_3), irrigation with SSW alone (T_4), irrigation with SSW along with zinc at 50 kg ha^{-1} (T_5), irrigation with SSW along with gypsum (T_6), irrigation with SSW along with FYM at 20 t ha^{-1} (T_7), irrigation with SSW along with combined application of Zn, gypsum and FYM (T_8).

The plot size was 4.05×9.0 m. Details of sowing and harvesting dates, variety, rainfall and irrigation water applied for cotton and wheat are presented in Tables 2 and 3, respectively. Depth of irrigation in all the treatments was kept at 7.5 cm. The irrigations were applied to the cotton and wheat based on Irrigation Water: Cumulative Pan Evaporation (IW/CPE) ratio of 0.4 and 0.8, respectively. Mean Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC) and Electrical Conductivity (EC) of the saline-sodic water was 5.45, 6.5 $mmol_c$ L^{-1} and 2.20 dS m^{-1}, respectively. The corresponding values for canal water were 1.29, 0.5 $mmol_c$ L^{-1} and 0.45 dS m^{-1}, respectively. Zinc and FYM were applied in respective treatments before sowing of the cotton crop and recommended rate of gypsum was applied before both crops. Application of gypsum is recommended when the *RSC* of irrigation water exceeds 2.5 $mmol_c$ L^{-1}. The quantity of gypsum was calculated on the basis of RSC of the poor quality water and number of irrigations of 7.5 cm applied to the previous crop. For each $mmol_c$ L^{-1} of *RSC* exceeding 2.5, the quantity of gypsum works out to be 0.25 t ha^{-1} for four irrigations of 7.5 cm. Before cotton, the quantity of gypsum varied from 0.75 to 1.25 t ha^{-1} (using water of 6.5 $mmol_c$ L^{-1}). But, for wheat, it remained 1.0 t ha^{-1} as only four irrigations were applied. The variation in gypsum application before cotton is due to variation in number of irrigations i.e. 3-5 applied to preceding wheat crop. The row spacing for cotton and wheat was kept at, respectively, 67.5 and 22.5 cm, and the plant to plant

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Table 2. Details of cotton crop cultivation during 2004-2010.

Particular	Year of study						
	2004	2005	2006	2007	2008	2009	2010
Date of sowing	27 April	23 April	25 April	8 May	13 May	10 May	4 May
Date of harvest	1 Nov	17 Nov	11 Nov	29 Oct	3 Nov	29 Oct	9 Nov
Variety	LH-1556	F-1861	RCH 134 *Bt*	RCH 134 *Bt*	RCH 134 *Bt*	RCH 134 *Bt*	RCH 134 *Bt*
Rainfall (mm)	315	532	371	245	345	223	409
IWA (cm)[a]	30	30	30	30	30	30	30

[a] Total Irrigation Water used.

Table 3. Details of wheat crop cultivation during 2004-2010.

Particular	Year of study						
	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011
Date of sowing	3 Dec, 2004	2 Dec, 2005	15 Nov, 2006	20 Nov, 2007	26 Nov, 2008	17 Nov, 2009	18 Nov, 2010
Date of harvest	11 April, 2005	11 April, 2006	11 April, 2007	11 April , 2008	16 April, 2009	11 April, 2010	15 April, 2011
variety	PBW-343	PBW-343	PBW 502	PBW 502	PBW-343	PBW-343	DBW 17
Rainfall (cm)	12.5	6.3	13.56	3.3	6.8	3.4	4.8
IWA (cm)	22.5	30	22.5	37.5	30	30	37.5

distance at 75 cm in cotton during all the 7 years of study.

Nitrogen (N) was applied to the cotton at the rate of 150 kg ha^{-1} (half at sowing and half at 50% flowering) in all years of the study. No phosphorus was applied to the soil before sowing of the cotton as recommended dose of phosphorus at 62.5 kg P_2O_5 ha^{-1} was applied to preceding wheat crop. Four sprays of 2% KNO_3 solution were applied to the cotton crop at weekly interval starting at flower initiation. Nitrogen was applied to wheat at the rate of 150 kg ha^{-1} (half at sowing and half at the time of first irrigation). Twenty six kg P ha^{-1} was drilled into the soil at sowing of wheat. All the recommended package of practices regarding sowing time, irrigation scheduling, weed and pest control were followed for both crops.

Wheat grain yield and cotton seed yield (lint+seed) were recorded in each plot after maturity of the crops. The yield attributing characters in cotton *viz.* plant height, number of monopodial branches per plant, number of sympodial branches per plant and number of bolls per plant were recorded from randomly selected 10 plants in each treatment. The plant height in wheat was recorded at the time of physiological maturity from randomly selected 10 plants in each treatment. Similarly, the effective tillers per m^2 were recorded from 2 places in each treatment. The soil samples were taken from 0-15 and 15-30 cm soil depths after the conclusion of the experiment. The soil samples were air dried and ground to pass through a 2- mm sieve. Soil pH and *EC* of soil samples (1:2, soil: water ratio) were determined using pH meter and conductivity bridge, respectively.

Results were statistically analyzed using standard procedures for randomized complete blocks design. Means were

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compared using Least Significant Differences (LSD) at 5% probability level.

RESULTS AND DISCUSSION

Crop Performance

The results pooled over 7 years revealed that irrigation with SSW resulted in a significant reduction in mean cotton seed yield from 2311 to 1832 kg ha^{-1} (20.7%) as compared to irrigation with CW (Table 4). Application of Zn and FYM along with SSW helped in improving cotton seed yield, but the increase was non-significant. Application of gypsum improved the cotton seed yield significantly over SSW and cotton seed yield reduction was only 8.8% as compared with CW only. When SSW was applied alternately with good quality CW, cotton seed yield reduction was only 6.1%. Addition of FYM in combination with gypsum and Zn increased the mean cotton seed yield significantly as compared with SSW alone. Mean cotton seed yield obtained under alternate irrigation with CW and SSW, and with addition of combination of all three amendments were statistically at par with the cotton seed yield obtained with CW alone. The trend of cotton seed yield was almost similar during all the years, except 2005 in which the effect of all the treatments was not significant due to more rainfall (532 mm) received during the growing season. Choudhary *et al.* (2011) reported that in calcareous soils, organic materials such as farmyard manure are effective in mobilizing Ca^{2+} from inherent and precipitated $CaCO_3$ resulting in improved soil properties, higher organic carbon content and higher yields of rice and wheat crops. The cotton seed yield reduction in SSW was accompanied by significant reduction in the number of bolls, sympods and monopods per plant (Table 5). Number of bolls per plant increased with use of amendments alone and in combination. Similarly, number of sympods increased with application of gypsum and with combined use of three amendments.

Results pooled over 7 years revealed that mean wheat grain yield was not significantly affected by different treatments (Table 6). The mean grain yield of wheat recorded was 7.4% more in SSW alone as compared with CW alone. During seven years of the experiment, except 2008, the grain yield increased with SSW as compared with CW. In 2007, the decrease in grain yield of wheat in SSW might be due to lower rainfall (3.3 cm) as compared to the other years. During the dry year, salts might affect the grain yield of wheat. However, during wet seasons (more rainfall), the salts remained away from the root zone due to less evaporation from the soil surface. Minhas *et al.* (1995) pointed out that alkali-water irrigated soils undergo cyclic precipitation of $CaCO_3$ during irrigation of wheat crop and its dissolution with rainwater depends upon

Table 4. Cotton seed yield as affected by different treatments during different years of experimentation.

Treatment	Cotton seed yield (kg ha^{-1})							
	2004	2005	2006	2007	2008	2009	2010	Mean
T_1	1044	2584	4232	1888	3261	1681	1485	2311
T_2	1129	3072	3738	2356	3436	2032	1943	2529
T_3	1157	2537	3928	1858	3210	1075	1411	2168
T_4	1210	2478	3605	791	2825	738	1180	1832
T_5	1358	2313	3626	929	2898	1291	1305	1960
T_6	1464	2459	3660	1163	3279	1441	1280	2107
T_7	1226	2793	3968	1299	3161	797	1344	2084
T_8	1443	2762	3752	1238	3294	1174	1409	2153
LSD (P= 0.05)	29.8	NS	300.4	142.9	329.7	216	353	262.2

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Table 5. Growth and development characteristics of cotton as influenced by quality of irrigation water and amendments (mean over 7 years).

Treatment	Mean plant height (cm)	Bolls plant^{-1} (No)	Sympods plant^{-1} (No)	Monopods plant^{-1} (No)
T_1	111	29.0	36.3	2.9
T_2	114	30.2	36.4	2.9
T_3	105	27.6	34.6	2.7
T_4	103	24.2	28.0	2.3
T_5	107	24.6	31.8	2.5
T_6	103	25.5	32.6	2.5
T_7	102	26.5	31.0	2.6
T_8	108	27.4	33.8	2.7
LSD (P= 0.05)	NS	2.80	4.06	0.30

Table 6. Grain yield of wheat as affected by different treatments during different years of experimentation.

Treatment	Wheat grain yield (kg ha^{-1})							
	2004	2005	2006	2007	2008	2009	2010	Mean
T_1	4028	4839	3479	4805	3472	3098	3276	3857
T_2	4291	4927	3481	4478	4053	3247	3820	4043
T_3	4540	4788	3459	4689	3274	3305	3403	3931
T_4	4250	5372	3764	4226	4109	3372	3916	4144
T_5	4287	5413	3164	4352	3880	3453	4031	4083
T_6	4208	5261	3235	4355	4381	3394	4085	4131
T_7	4042	4668	3455	4364	3584	3497	3932	3935
T_8	4220	5406	3716	4140	4004	3545	4192	4175
LSD (P= 0.05)	NS	196.6	NS	51.8	114.5	178	576	NS

rainfall received during monsoons. They further observed that sustained yields are possible when irrigation is practiced with alkali waters (RSC> 4.0 mmol$_c$ L^{-1}) in areas having annual rainfall of 500 mm.

The yield increase in wheat due to the supply of SSW may be due to the improvement in hidden Sulphur (S) deficiency owing to the presence of SO_4 ions in SSW. Although no visual S deficiency symptoms were noticed in the experimental wheat crop, in adjoining areas of similar soil texture, S deficiency has been reported where only canal water is applied for irrigation (Anonymous, 2005). The S deficiency symptoms were noticed in wheat crop during 2004 when more rainfall was recorded in January. The deficiency was corrected by using Gypsum at 125 kg ha^{-1}. Choudhary *et al.* (2011) also observed that wheat yield was not affected significantly up to nine years in a calcareous soil irrigated with sodic water having even higher sodicity (residual sodium carbonate of 10 mmol$_c$ L^{-1}). These results suggest that deleterious effects of poor quality water in this calcareous soil having loamy sand texture (higher leaching owing to high infiltration rate) failed to reach a threshold value for salinity and alkalinity at which wheat yields are reduced.

Soil Properties

The continuous application of SSW in cotton-wheat cropping system significantly increased soil pH to 9.15 in 0-15 and to 9.40 in 15-30 cm layers as compared to the soil that received good quality CW (pH= 8.40) (Table 7). The soil pH values were higher in lower depth of 15-30 cm than top 0-15 cm soil layer which might be due to leaching of salts to lower layer. The increase in soil pH was significantly higher in all the treatments,

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Table 7. Effect of quality of irrigation water and amendments on soil pH and electrical conductivity after 7 years of experimentation.

Treatment	pH[a]		*EC* (dS m^{-1})[a]	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1	8.40	8.40	0.216	0.183
T_2	8.33	8.34	0.203	0.179
T_3	8.79	9.12	0.240	0.237
T_4	9.15	9.40	0.445	0.624
T_5	9.12	9.30	0.429	0.448
T_6	9.01	9.23	0.419	0.436
T_7	9.13	9.30	0.478	0.534
T_8	9.13	9.27	0.419	0.309
LSD (P= 0.05)	0.06	0.07	0.0675	0.0384

[a] Measured in 1:2 soil water ratio.

where SSW was applied as compared to treatments with CW alone or alternately was applied with SSW. With the application of Zn or gypsum or FYM alone and combined use of all the amendments, the pH values reduced significantly as compared to SSW alone in 15-30 cm soil layer.

Similarly, *EC* of soil increased significantly with the application of SSW as compared to CW alone or alternately with SSW. The use of poor quality waters for long periods of time results in increased pH and *EC*, and creates a hostile soil environment which adversely affects plant growth and results in clay dispersion and clogging of pores due to clay migration (Grattan and Oster, 2003). The *EC* in 15-30 cm soil layer was reduced significantly with the application of different amendments alone or combined, but the differences were non- significant in the 0-15 cm soil layer.

At the end of the experiment, the available nitrogen, phosphorus, potassium, and organic carbon content of the soil were higher in the treatments where CW was applied along with Zn, FYM, and gypsum. It might be owing to the beneficial effect of farmyard manure and gypsum on soil physical properties as well as addition of nutrients through farmyard manure (Table 8). The micronutrients content (iron, zinc, manganese and copper) after seven years of the experiment were not significantly different among the treatments (data not shown). However, the mean contents of iron, zinc, manganese and copper in surface layer were 11.6, 8.14, 6.19 and 1.48 ppm, respectively.

The deleterious effects of SSW were significant on cotton crop, although it was

Table 8. Available nutrients and organic carbon contents of soil samples at different depths under various treatments.

	N (kg ha^{-1})		P_2O_5 (kg ha^{-1})		K_2O (kg ha^{-1})		OC (%)	
Treatments	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
T 1	463.67	362.87	33.87	15.25	324.80	219.80	0.372	0.115
T 2	472.67	409.90	32.45	12.62	372.40	243.60	0.375	0.126
T 3	403.20	367.35	29.10	11.57	348.60	245.00	0.305	0.215
T 4	376.32	315.85	28.45	10.37	344.40	221.20	0.227	0.137
T 5	353.92	306.90	22.55	10.77	303.80	245.00	0.292	0.187
T 6	324.80	349.42	25.85	11.30	298.20	201.60	0.312	0.178
T 7	403.22	288.92	26.67	10.02	438.20	238.20	0.345	0.180
T 8	383.02	313.25	27.45	14.02	425.60	277.80	0.290	0.147
LSD (P= 0.05)	76.29	70.18	NS	NS	NS	NS	NS	NS

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grown during monsoonal rainy season which received sufficient amounts of rainwater (Table 2). Suarez *et al.* (2006) also observed that under a combined rain-irrigation water use, the soil may go from relatively saline condition to a non-saline condition in the upper part of the profile after a significant rain. Under such conditions the decrease in Sodium Adsorption Ratio (SAR) will be slower than the decrease in *EC*. This condition causes a potential sodium hazard leading to dispersion, loss of aggregate stability, and decrease in infiltration rate during the rain event. However, the extent to which a sodic soil adversely responds to de-ionized water does not depend upon the quantity of rainfall alone, but is also related to the extent to which the soil can maintain an elevated EC as a result of mineral dissolution, primarily due to the presence and reactivity of $CaCO_3$ (Shainberg *et al.*, 1981). Thus, it seems that monsoonal rainfall during cotton growing season may be responsible for yield reduction owing to sodium hazard that exists when irrigated with SSW (Suarez *et al.*, 2006). But the presence of $CaCO_3$ might have reduced the adverse effects. Small increase in soil pH may be ascribed to mobilization of Ca from inherent $CaCO_3$ present in the soil. The saline-alkali water used for irrigation was of marginal alkalinity, (mean RSC of 6.4 $mmol_c$ L^{-1}) which might have enabled the soil to maintain the Ca concentration in soil solution within nutritionally adequate amounts for crops (Pratt and Suarez, 1990).

CONCLUSIONS

The results revealed that application of saline sodic water decreased the cotton seed yield but wheat yield was not adversely affected. The mean cotton seed yield obtained under alternate irrigation with canal water and saline sodic water, and with addition of farmyard manure was statistically at par with the cotton seed yield obtained with canal water alone. The implementation of alternate irrigation of saline sodic water with canal water will produce sustainable yields as reduced (only 50%) quantity of saline sodic water will reduce the deteriorating effect on cotton seed yield and soil properties. The results of this study suggest that sustainable yields of cotton-wheat cropping system while using poor quality saline sodic water can be achieved with the application of farmyard manure to cotton in these light-textured calcareous soils of northwestern India. It suggests that in calcareous soils, farmyard manure can be quite useful in ameliorating long-term effects of saline sodic irrigation and sustaining the productivity of cotton-wheat system.

REFERENCES

1. Ahmed, S., Ghafoor, A., Qadir, M. and Abbas, A. M. 2006. Amelioration of a Calcareous Saline-Sodic Soil by Gypsum Application and Different Crop Rotations. *Int. J. Agric. Biol.,* **42**: 142-146.
2. Anonymous 2005.Wheat. In: *"Package of Practices for Crops of Punjab-Rabi Crops*", (Ed.): Mahindra, K. Punjab Agricultural University, Ludhiana, India, **22.**
3. Boumans, J. H., van Hoorn, J. W., Kruseman, G. P. and Tanwar, B. S. 1988. Water Table Control, Reuse and Disposal of Drainage Water in Haryana. *Agric. Water Manage.,* **14**: 537-545.
4. Chaudhary, O. P. 2003. Management of Poor Quality Waters for Rice-Wheat Cropping System. *In:* "Nutrient Management for Sustainable Rice-Wheat Cropping System", (Eds.): Yadvinder-Singh *et al*., National Agric Tech Project, Indian Council of Agricultural Research, New Delhi, PP. 330-343.
5. Chaudhary, O. P. and Ghuman, B. S. 2008. Cyclic Use of Sodic and Non-sodic Canal Waters for Irrigation in Cotton-Wheat Cropping System in Semi-Arid Region. *J. Sustain. Agric.,* **32**: 269-286.
6. Chaudhary, O. P., Ghuman, B. S., Bijay-Singh, Thuy, N. and Buresh, R. J. 2011. Effects of Long-Term Use of Sodic Water Irrigation, Amendments and Crop Residues on Soil Properties and Crop Yields in Rice-

Wheat Cropping System in a Calcareous Soil. *Field Crop. Res.,* **121**: 363-372.
7. Curtin, D., Seelers, F. and Steppuhn, H. 1995. Sodium-Calcium Exchange Selectivity as Influenced by Soil Properties and Method of Determination. *Soil Sci.,* **159**: 176-184.
8. Datta, K. K. and De Jong, C. 2002. Adverse Effect of Water Logging and Soil Salinity on Crop and Land Productivity in Northwest Region of Haryana, India. *Agric. Water Manage.,* **57**: 223-238.
9. Grattan, S. R. and Oster, J. D. 2003. Use and Reuse of Saline-Sodic Waters for Irrigation of Crops. *J. Crop Prod.,* **7:** 131-162.
10. Knudsen, D., Peterson, G. A. and Pratt, P. F. 1982. Lithium, Sodium and Potassium. Part 2. In: "*Methods of Soil Analysis*", (Eds.): Page A. L., Miller, R. H. and Keeney, D. R. 2nd Edition, Agron. Monogr. 9, ASA, SSSA, Madison, WI, PP. 225-246.
11. Lal, K., Khan, I. and Yadav, G. 2008. Irrigation Water and Release of Ions from Soil Mineral Weathering. In: *"Diagnosis and Management of Poor Quality Water and Salt Affected Soils*", (Eds.): Lal, K., Meena, R. L., Gupta, S. K., Singh, G. and Singh, G. Central Soil Salinity Research Institute, Karnal, India, PP. 116-121.
12. Minhas, P. S., Sharma, D. R. and Chauhan, C. P. S. 2004. Management of Saline and Alkali Waters for Irrigation. *In: "Advances in Sodic Land Reclamation, International Conference on Sustainable Management of Sodic Lands*", 9-14 Feb. 2004, Central Soil Salinity Research Institute, Lunknow, India, PP. 121-162.
13. Minhas, P. S., Sharma, D. R. and Singh, Y. P. 1995. Response of Rice and Wheat to Applied Gypsum and Farmyard Manure on an Alkali Water Irrigated Soil. *J. Indian Soc. Soil Sci.,* **43**: 452-455.
14. Minhas, P. S. and Bajwa, M. S. 2001. Use and Management of Poor Quality Water for the Rice-Wheat Based Production System. *J. Crop Prod*., **4**: 273-305.
15. Nelson, D. and Sommers, L. E. 1996. Total Carbon, Organic Carbon and Organic Matter. Part 3. In: *"Methods of Soil Analysis*", (Eds.): Sparks, D. L., Sparks, D. L., Page, A. L., Helmke, P. A. and Loeppert, R. H. SSSA, Madison, WI, PP. 961-1010.
16. Olsen, S. R., Cole, C. V., Watanabe, F. S. and Dean, L. A. 1954. E*stimation of Available Phosphorus by Extraction with Sodium Bicarbonate*. USDA Circular, 939 PP.
17. Pratt, P. F. and Suarez, D. L. 1990. Irrigation Water quality Assessment. In: "*Agricultural Salinity Assessment and Management*", (Ed.): Tanji, K. K. American Society of Civil Engineers, New York. Pp. 340-370.
18. Shainberg, I., Rhoades, J. D., Suarez, D. L. and Prather, R. J. 1981. Effect of Mineral Weathering on Clay Dispersion and Hydraulic Conductivity of Sodic Soil. *Soil Sci. Soc. Am. J.,* **45**: 287-291.
19. Suarez, D. L., Wood, J. D. and Lesch, S. M. 2006. Effect of SAR on Water Infiltration under a Sequential Rain-Water Management System. *Agric. Water. Manage.,* **86**: 150-164.

مدیریت آب شور-سدیمی در سامانه کشت پنبه-گندم

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چکیده

به منظور ارزیابی اثر مواد بهساز برای کم کردن اثرات مخرب آب شور-سدیمی در یک خاک آهکی زیر سامانه کشت پنبه-گندم، آزمایشی دراز مدت برای ۷ سال اجرا شد. نتایج تجمیعی ۷ ساله

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آشکار ساخت که کار برد آب شور–سدیمی در مقایسه با آب کانال که کیفیت خوبی داشت منجر به کاهش ۲۰/۷٪ میانگین عملکرد پنبه دانه شد. با این همه، کیفیت آب آبیلری روی عملکرد دانه گندم تاثیر منفی نداشت. در میان مواد بهساز، گچ و کود دامی در کاهش اثر آب شور–سدیمی از بقیه مواد موثرتر بودند. در مقایسه با آب دارای کیفیت خوب، در تیمار (آب شور–سدیمی) کود دامی،کاهش عملکرد پنبه دانه برابر ۹/۸٪ بود و در تیمار مصرف گچ در حد ۸/۸٪ باقی ماند. اما، در تیماری که آب شور وسدیمی به طور متناوب با آب کانال که کیفیت خوب داشت مصرف می شد، کاهش عملکرد پنبه دانه فقط ۶/۱٪ بود. این نتایج گواهی می دهد که کار برد کود دامی در خاک آهکی در کاهش صدمات دراز مدت ناشی از آب شور وسدیمی و حفظ توان تولید و بهره وری سامانه پنبه–گندم مفید است.

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