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Effect of irrigation water salinity and nitrogen on growth, fodder yield, water productivity and profitability of oats (*Avena sativa*)

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ABSTRACT

An experiment consisting of four irrigation water salinity levels [Good quality water (0.69 dS m^{-1}), 2 EC, 4 EC and 6 EC water] and four N levels (0, 50, 100 and 125 % recommended dose of N) was conducted to find out the effect on growth and yield of fodder oats. Irrigation water upto 4 EC did not influence growth parameters and yield significantly but the decrease was significant at 6 EC irrigation water compared to good quality water. Application of 125% recommended dose of N (188 kg ha^{-1}) significantly increased the growth traits, N uptake and green fodder yield of oats. The interaction effect of irrigation water salinity and nitrogen was found to be non-significant. Water productivity and profitability of fodder oats did not decrease significantly upto 4 EC irrigation water but responded favourably to N application.

***Key words*: green fodder, N uptake, nitrogen, water productivity, water salinity**

Introduction

Oat (*Avena sativa L.*) locally known as 'Javi' is an important *rabi* cereal usually cultivated under irrigated conditions of northern and north-western region of India, covering an area of 5, 00,000 ha in the country (IGFRI, 2011). It ranks sixth in world cereal production following wheat, maize, rice, barley, sorghum and has a tremendous capacity to produce high quality green fodder for livestock because of its excellent regeneration capacity. For fodder production, two to four cuts are taken from December to April and then crop is allowed to set seed.

The scarcity of good quality irrigation water is one of the major issues round the globe as saline water resources are more abundant than fresh water. India is having nearly 25% of the groundwater resources as saline/ brackish; bringing these resources into sustainable productive use will offer opportunities to increase agricultural production, especially in developing countries like India. The crops grown for grain production are more sensitive to irrigation water salinity as comparison to fodder crops. It is well documented that oats showed the minimum yield reduction compared with its yield in normal soil, demonstrating its tolerant nature (Yadav and Kumar, 1997). Among the major plant nutrients, nitrogen plays a pivotal role in quantitative as well as qualitative improvement in the productivity of fodder. It plays an essential role in many critical functions such as photosynthesis in the plant and is a major component of amino acids, which are the precursors of proteins. N results in rapid growth of the plants and helps in increasing production per unit area and time.

Material and methods

The experiment was laid out in Factorial Randomised Block Design which consisted of sixteen treatment combinations, four irrigation water salinity levels [Good quality water (0.69 dS m^{-1}), 2 EC, 4 EC and 6 EC water] and four N levels [0, 50, 100 and 125 % recommended dose of N (RDN)] with three replications. Irrigation water was prepared using salts of sodium, calcium and magnesium keeping Ca and Mg ratio 2:1 and SAR at 5. Soil of the lysimeters was low to medium in available nitrogen, medium in available phosphorus and high in available potassium. Initial pH of the top 0-15 cm soil ranged between 7.5-7.7 and EC ranged from 0.180- 0.260 dS m^{-1}. Total three irrigations were given including pre-sowing irrigation using different treatments of saline water. A basal dose of 60 kg P_2O_5 ha^{-1} and 40 kg K_2O ha^{-1} was applied in all the plots at the time of sowing. Crop was fertilized with different dose of nitrogen as per the treatment, which was given in the form of urea; 1/3 at sowing, 1/3 at first irrigation and 1/3 at first cut. The recommended dose of N for the region is 150 kg ha^{-1}. Seeds were sown by *kera* method in rows 20 cm apart on marked lines. Observations on plant height, number of tillers/plant, number of leaves/plant, green fodder yield, leaf area index, chlorophyll content, N content and its uptake, irrigation as well as total water productivity and economics of cultivation recorded and statistical analysis was done using standard procedures of analysis of variance in RBD using IRRISTAT software (IRRI, 1999), and statistical mean differences were found by Fisher's protected least significant difference test at P <0.05.

Results and discussion

Growth attributes

Plant height, number of tillers and leaves per plant decreased with increasing levels of irrigation water salinity at all periodic observations, though the reduction in parameters was significant only at 6 EC water (Table 1). It can be ascribed to the fact that higher salt concentration results in more negative osmotic (ψ_s) and water potential (ψ_w) of soil solution and thus makes it more difficult for plants to absorb water and nutrient from the soil, even if the soil appears quite moist. In fact, the plant suffers from a form of drought (physiological drought) which results in retarded growth. Increasing N levels (125% of RDN) increased the plant height, number of tillers and leaves per plant significantly. Higher nitrogen availability with higher level of N application favoured the plant growth. Sharifi and Taghizadeh (2009) also reported increased plant height with increase in levels of N application in fodder maize. The findings are also in conformity with Singh *et al.* (1999).

Leaf area index (LAI) decreased steadily with increasing levels of irrigation water salinity at both cuts; however, the reduction was non-significant up to 4 EC at 1st cut and up to 6 EC at 2nd cut (Table 1). Similarly, at first cut, 'a' 'b' and total chlorophyll content decreased with increasing levels of irrigation water salinity. Increased N levels increased the leaf area index at both cuts similarly, 'a' 'b' and total chlorophyll content was significantly higher at both the cuts with 125% RDN (Fig.1). This could be attributed to the lower synthesis of plant tissues as well as chlorophyll. Sharma (2009) also reported LAI of 7.93 and 10.08, respectively, at 1st and 2nd cut by application of 150 kg N ha^{-1} in fodder oat.

Marginal decrease in N content with increasing levels of irrigation water salinity was observed at both cuts, but the reduction was non-significant for both the cuts (Table 2). This could be attributed to the lower N uptake by plant due to higher accumulation of salts in the rhizosphere. Reduction in N accumulation in plants has been reported in a number of laboratory and greenhouse studies (Cram, 1973; Pessarakli and Tucker, 1988; Al-Rawahy *et al.,* 1992). Reduction in N accumulation is understandable as Cl^- (saline condition) and NO_3^- (present in soil) have antagonistic effects on uptake of each other. On the other hand higher availability of N with 125% RDN compensated the reduction due to salinity, and favoured the uptake of N and its content in fodder oat.

Yield

Across N levels green fodder yield of oats at both cuts was statistically similar up to 4 EC irrigation water salinity, thereafter the decrease in green fodder yield was significant as compared to good quality water irrigation (Table 3). Kumar and Sharma (1995) also reported that fodder oat can safely be irrigated with saline water up to 5 EC without significant yield reduction under Karnal conditions. The primary effect of high irrigation water

Table 1. Effect of irrigation water salinity and N levels on growth attributes of fodder oats

Irrigation water quality ($dS\ m^{-1}$)	Plant height (cm) Days after sowing 30	45	60	No. of tillers $plant^{-1}$ Days after sowing 30	45	60	No. of leaves $plant^{-1}$ Days after sowing 30	45	60	Leaf area index 1st cut	2nd cut
Good quality water	42.5	68.5	87.1	4.95	7.47	8.17	18.8	26.7	35.9	5.75	9.66
2 EC	42.0	67.6	87.1	4.93	7.44	8.16	18.4	26.2	35.8	5.65	9.40
4 EC	40.2	65.9	86.8	4.83	7.25	8.10	17.5	25.7	35.5	5.40	9.03
6 EC	37.6	61.6	77.9	4.43	6.90	7.81	15.9	24.2	34.6	4.21	7.90
S.Em±	1.5	1.9	1.2	0.29	0.35	0.23	1.4	1.2	1.2	0.35	0.71
CD (P=0.05)	4.2	5.5	3.4	NS	NS	NS	NS	NS	NS	1.03	NS
Recommended dose of N (%)											
0	37.6	61.5	81.8	4.21	6.71	7.75	14.5	23.6	34.1	4.78	6.97
50	39.1	64.5	85.2	4.51	7.20	8.18	17.7	25.6	35.6	5.36	8.17
100	40.5	66.3	86.7	4.73	7.44	8.46	18.3	26.8	36.7	5.86	9.20
125	41.8	67.3	87.2	4.91	7.61	8.54	18.5	27.7	36.7	5.91	10.01
S.Em±	1.5	1.9	1.2	0.29	0.35	0.23	1.4	1.2	1.2	0.35	0.71
CD (P=0.05)	NS	5.5	3.4	NS	NS	0.68	4.0	3.5	NS	1.03	2.05

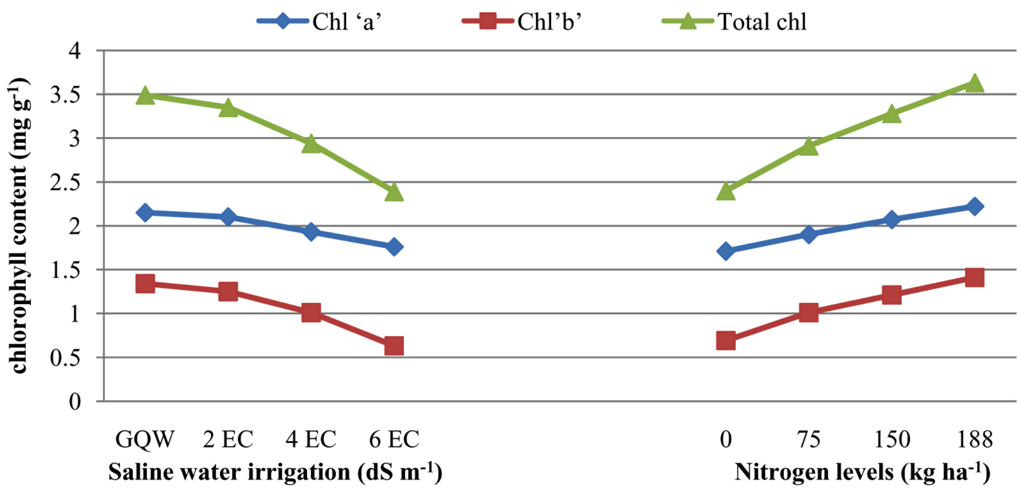

Fig. 1. Chlorophyll content of oats at 2nd cut as affected by irrigation water salinity and N levels

Table 2. Nitrogen content and its uptake as affected by irrigation water salinity and N levels

Irrigation water quality (dS m^{-1})	N content (%)		N uptake (kg ha^{-1})		
	1st cut	2nd cut	1st cut	2nd cut	Total
Good quality water	1.97	1.85	77.2	134.4	211.7
2 EC	1.95	1.84	74.7	132.4	207.1
4 EC	1.90	1.79	64.9	125.9	190.8
6 EC	1.78	1.62	54.2	111.4	165.6
S.Em±	0.08	0.10	4.8	9.4	11.3
CD (P=0.05)	NS	NS	13.9	27.1	32.6
Recommended dose of N (%)					
0	1.52	1.48	46.3	93.7	140.0
50	1.82	1.65	60.9	115.3	176.2
100	2.03	1.81	72.5	132.8	205.3
125	2.09	1.91	79.1	145.8	224.9
S.Em±	0.08	0.10	4.8	9.4	11.3
CD (P=0.05)	0.24	NS	13.9	27.1	32.6

Table 3. Effect of irrigation water salinity and N levels on green fodder yield of oats

Irrigation water quality (dS m^{-1})	Green fodder yield (t ha^{-1})		
	1st cut	2nd cut	Total
Good quality water	30.3	57.2	87.5
2 EC	30.1	55.8	85.9
4 EC	28.7	53.3	82.0
6 EC	24.9	50.2	75.1
SEm±	1.3	1.7	2.5
CD (P=0.05)	3.7	5.0	7.2
Recommended dose of N (%)			
0	24.8	48.5	73.3
50	27.7	52.4	80.6
100	30.4	56.5	86.9
125	30.9	59.2	90.1
SEm±	1.3	1.7	2.5
CD (P=0.05)	3.7	5.0	7.2

salinity generally renders less water available to plants in spite of the fact that some water is still present in the root zone. This is because of osmotic pressure of the soil solution become more negative as the salt concentration increases. Apart from the osmotic effect of salts in the soil solution, excessive concentration and absorption of individual ions may also prove toxic to the plants and/or may retard the absorption of other essential plant nutrients (Qadar, 2009). Lower osmotic potential of soil resulting from the good rainfall received after 1st cut encouraged the profuse growth of fodder which ultimately increased the green fodder yield appreciably in 2nd cut. Increasing N levels increased the green fodder yield significantly up to 125% RDN, however, increase was significant only upto 100% RDN for the second cut.Significant increase in green fodder yield can be attributed to greater plant height, more number of leaves per plant and leaf area index. The abundant supply of nitrogen may have increased protoplasmic constituents and accelerated the process of

Table 4. Water productivity and economics of fodder oats as affected by irrigation water salinity and N levels

Irrigation water quality (dS m^{-1})	Irrigation water (cm)	Rain fall (cm)	GFY (t ha^{-1})	IWP (kg m^{-3})	TWP (kg m^{-3})	Cost of cultivation (× 10^3 ₹ ha^{-1})	Gross returns (× 10^3 ₹ ha^{-1})	Net returns (× 10^3 ₹ ha^{-1})	B:C ratio
Good quality water	17.0	19.40	87.5	51.5	24.1	56.2	100.7	44.5	1.79
2 EC	17.0	19.40	85.9	50.5	23.6	56.2	96.7	40.5	1.72
4 EC	17.0	19.40	82.0	48.2	22.5	56.2	92.3	36.1	1.64
6 EC	17.0	19.40	75.1	44.2	20.6	56.2	85.3	29.1	1.52
S.Em±	-	-	2.49	2.08	0.79	-	-	2.89	0.05
CD (P=0.05)	-	-	7.19	5.99	2.29	-	-	8.37	0.15
Recommended dose of N (%)									
0	17.0	19.40	73.3	43.1	20.1	55.0	84.3	29.3	1.53
50	17.0	19.40	80.6	47.4	22.2	55.8	90.4	34.5	1.62
100	17.0	19.40	86.9	51.1	23.9	56.7	96.4	39.6	1.70
125	17.0	19.40	90.1	53.0	24.7	57.2	100.2	43.0	1.75
S.Em±	-	-	2.49	2.08	0.79	-	-	2.89	0.05
CD (P=0.05)	-	-	7.19	5.99	2.29	-	-	8.37	0.15

GFY: green fodder yield; IWP: irrigation water productivity; TWP: Total water productivity

cell division and elongation, which has resulted in luxuriant vegetative growth in terms of plant height,thereby, higher biomass and dry matter yield. Ahmad *et.al.* (2011) also reported 74.67 t/ha total green fodder yield of oat by application of 150 kg N/ha.

Water productivity and Economics

Irrigation water productivity (IWP) and total water productivity (TWP) of total green fodder was statistically similar up to 4 EC irrigation water salinity, but decreased significantly at 6 EC compared to good quality water (Table 4). All the saline water treatments considered to be naturally available. Highest gross returns (₹ 1,00,725 ha^{-1}), net returns (₹ 44,500 ha^{-1}) and B:C ratio (1.79) were recorded with application of good quality irrigation water but the decrease in all the economic variables was non-significant upto 4 EC irrigation water. This can be ascribed to lower fodder yields due to saline water irrigation. Significant increase in IWP and TWP of total green fodder yield was observed up to 100% RDN. Increasing N levels increased gross returns, net returns and B:C ratio. Dadarwal *et al.* (2009) also observed an increase in net returns and Singh *et al.* (2010) reported increase in B:C ratio with increasing dose of N fertilizer application.

Conclusion

Based on the results of present study it may be concluded that fodder oat can be successfully grown using saline water irrigation up to 4 EC with 125% recommended dose of N (188 kg ha^{-1}). The decrease in net returns and B:C ratio was also non-significant up to 4 EC saline water. There is further need to screen the yield potential of oats genotypes and pattern of nitrogen use under salt stress conditions.

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References

Ahmad, A. H., Wahid, A., Khalid, F., Fiaz, N. and Zamir, M.S.I. 2011. Impact of organic and inorganic sources of nitrogen and phosphorus fertilizers on growth, yield and quality of fodder oats (*Avena sativa L.*). *Agronomical Research in Moldavia* **XLIV**(3)**:** 39-49.

Al-Rawahy, S.A., Stroehlein, J.L. and Pessarakli, M. 1992. Dry matter yield and nitrogen-15, Na, Cl and K Content of tomatoes under sodium chloride stress. *Journal Plant Nutrition* **15:** 341-358.

Cram, W.J. 1973. Internal factors regulating nitrate and chloride influx in plant cells. *Journal Experimental Botany* **24:** 328-341.

Dadarwal, R. S., Jain, N. K. and Singh, D. 2009. Integrated nutrient management in baby corn (*Zea mays*). *Indian Journal of Agricultural Sciences* **79:** 1023-1025.

Indian Grassland and Fodder Research Institute. 2011. *Vision: 2030*. pp.2.

IRRI.1999. IRRISTAT for windows version 4.0. Biometric Unit, IRRI, Los Banos, Philippines.

Kumar, A. and Sharma P.C. 1995. Effect of salinity on the performance and ionic concentration in *rabi* forage crops. *Forage Research* **21:** 87-90.

Pessarakli, M. and Tucker, T.C. 1988. Dry matter yield and nitrogen-15 uptake by tomatoes under sodium chloride stress. Soil *Science Society America Journal* **52:** 698-700.

Qadar, A. 2009. Alleviation of salt stress through nutrient management. In: *Enhancing Nutrient Use Efficiency in Problem Soils* (Eds. Singh, G., Qadar, A., Yaduvanshi, N.P.S. and Dey, P.). Central Soil Salinity Research Institute, Karnal, India, pp.132-157.

Sharifi, R. S. and Taghizadeh, R. 2009. Response of maize (*Zea mays* L.) cultivars to different levels of nitrogen fertilizer. *Journals of food Agriculture and Environment* **7:** 518-521.

Sharma, K.C. 2009. Integrated nitrogen management in fodder oats (*Avena sativa*) in hot arid ecosystem of Rajasthan. *Indian Journal of Agronomy* **54:** 459-464.

Singh, M.K., Singh, R.N., Singh, S.P., Yadav, M.K. and Singh, V.K. 2010. Integrated nutrient management for higher yield, quality and profitability of baby corn (*Zea mays*). *Indian Journal of Agronomy* **55:** 100-104.

Singh, M.M., Srivastava S.K. and Singh, A.K. 1999. Effect of nitrogen and sulphur on forage yield and protein content of oat *(Avena sativa)*. *Indian Journal of Agricultural Sciences* **69:** 731-732.

Yadav, R. K. and Kumar, A. 1997. Feasibility of cultivating different forage crops on saline soils. *Crop Research* **13:** 45-49.

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Quality of underground irrigation water and their effects on soil properties of Tonk district of Rajasthan

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ABSTRCT

An investigation was undertaken with the objectives to determine the quality of underground water of Uniara and Newai Panchayat samiti of Tonk district, their effect on soil properties and to categorize them for their suitability for irrigation. The soils of Uniara Panchayat Samiti are clay loam soil and sandy loam textured soil in Newai panchayat samiti of Tonk district. Total 343 underground water samples were collected from different villages and surface soil samples were also collected from these fields which are being irrigated with corresponding waters. As per water quality classification 37.1, 4.3, 24.3, 20.0 and 15.7 percent water samples falls under good, marginally saline, marginally alkali, alkali and highly alkali categories in Uniara Panchayat Samiti, whereas 25.7, 8.6, 2.9, 28.6, 24,3 and 14.3 percent are under good, marginally saline, saline, marginally alkali, alkali and highly alkali categories in Newai Panchayat Samiti, respectively. As per ionic dominance of cations in underground water were sodium followed by calcium and in anions bicarbonate followed by chloride and carbonates in anions. Decreasing water table results in increasing salt concentration in water. The clay loam soils having higher values of EC, pH and SAR as compared to the sandy loam soils.

Key words: Alkali water, marginal quality water, poor quality water, saline water, SAR

Introduction

Saline or alkali waters constitute an important source of irrigation for agricultural production in water scares 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. The detailed information is lacking as regard of quality of underground waters of Tonk district. Therefore it is very essential to categorize the underground waters use for irrigation with respect to their suitability for crops and soils.

Materials and methods

The study was carried out in Uniara Panchayat Samiti (PS) of Tonk district situated in North-Eastern part of Rajasthan state of India which located at 23^0 3'- 30^0 12' N latitude and $69^0$30'- $78^0$17' E longitude. Soil of the district falls under category of old alluvial plains in semi-arid region. The colour of soils ranges from grayish brown to yellowish brown and texture of soil are sandy loam to clay loam in texture (Dhir and Singh, 1985). Tonk district is situated in South-eastern Rajasthan, comprising of six PS *viz* Tonk, Niwai, Deoli, Uniara, Malpura & Toda. Out of six, two PS *viz.* Niwai and Uniara were taken for the study. The climate of this area is semiarid type. The mean annual rainfall (1901-2008) of the district is 610mm. Total annual Potential evapotranspiration computed by penman's method is 1725.0mm. The potential evapotranspiration rate generally is highest (255.0 mm) during the month of May and lowest (68.0 mm) in the month of December. Pearlmillet, groundnut, clusterbean, sesame, greengram are grown in kharif and mustard, wheat and chickpea crops are dominant crops in rabi season. The major sources of irrigation are dug well, tubewell,/Bore wells, Pond, canals etc and net irrigated area is 41 percent in the district.

Three hundred forty three (343) ground water samples were collected from 140 villages of Uniara PS and Newai PS of Tonk district 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. The fluoride content in ground water was determined by using specific ion analyzer with F electrode (Orion). 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). Surface soil samples were also collected from these fields which are being irrigated with corresponding waters. 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 and sodium adsorption ratio of soil samples were determined as per U.S.D.A. Hand book 60 (Richards, 1954). The correlations between soil properties and water characteristics were worked out.

Results and discussion

Quality of water and its effect on soil

The water table of Uniara PS area varied from 11 to 24m. The variations in EC, pH, RSC and SAR ranges of underground waters were 0.28 to 6.30dS m^{-1}, 7.4 to 8.9, nil to 14.52m.e. L^{-1} and nil to 23.26, respectively (table 1). Dominating cations ranges in these waters of this PS were sodium from 0.16 to 49.34 m.e. L^{-1} followed by calcium from 0.28 to 13.61m.e. L^{-1} and anions from 0.37 to 21.68m.e. L^{-1} bicarbonate followed by 0.18 to 8.69m.e. L^{-1} chloride. Mean values of anions for HCO^{3-}, CO_3^{2-}, Cl^- and SO_4^{2-} were 6.40, 1.04, 2.45 and 0.72 m.e. L^{-1}, whereas, Na^+, Ca^{2+}, Mg^{2+} and K^+ were 8.19, 3.18, 0.44 and 0.07 m. e. L^{-1}, respectively. It was further observed that underground waters of Uniara PS are $HCO^{3-} > Cl^- > CO_3^{2-} > SO_4^{2-}$ type in respect of cations and $Na^+ > Ca^{2+} > Mg^{2+} > K^+$ in respect of anions. Based on EC and derived parameters i.e. SAR and RSC, the water samples were classified suggested by Gupta *et al.* (1994). According to these criteria 37.1, 4.3, 24.3, 20.0 and 15.7 percent water samples were under good, marginally saline, marginally alkali, alkali and highly alkali categories in Uniara PS, respectively (table 3). It was observed that increasing in depth of water table increases the concentration of anions and cations in underground water. Correlation studies revealed that water table significantly and positively correlated with EC, SAR and RSC of irrigation water (r= 0.509**, 0.718** and 0.738**). Similarly water table also significantly and positively correlated with fluoride content (r= 0.813**) in underground water was observed.

In Newai PS water table depth varied from 10 to 26m. The variations in EC, pH, RSC and SAR ranges of underground waters varied from 0.20 to 7.31dS m^{-1}, 7.5 to 9.3, nil to 15.23m.e. L^{-1} and nil to 24.47, respectively (table 1). Dominating cations in these waters of this PS area were sodium which ranged from 0.16 to 59.69 m.e. L^{-1} followed by calcium from 0.20 to 16.22 m.e. L^{-1}. In anions dominance of bicarbonate ranges from 0.40 to 24.22 m.e. L^{-1} bicarbonate followed by 0.05 to 12.04m.e. L^{-1} chloride. Mean values of anions for HCO^{3-}, CO_3^{2-}, Cl^- and SO_4^{2-} were 7.11, 0.85, 1.44 and 0.76m.e. L^{-1}, whereas, Na^+, Ca^{2+}, Mg^{2+} and K^+ were present 9.12, 2.83, 0.41 and 0.05 m. e. L^{-1}, respectively. As per classification 25.6, 8.6, 2.9, 28.6, 24.3 and 14.3 percent water samples were under good, marginally saline, saline, marginally alkali, alkali

Table 1. Characteristics of tube well/open well waters

Characteristics	Uniara	Mean	Niwai	Mean
pH	7.4 to 8.9	7.9	7.5 to 9.3	8.0
EC (dS m^{-1})	0.28 to 6.30	0.60	0.20 to 7.31	0.61
HCO_3^- (m.e. L^{-1})	0.37 to 21.64	6.40	0.40 to 24.22	7.11
CO_3^{2-} (m.e. L^{-1})	Nil to 3.87	1.04	Nil to 4.57	0.85
Cl^- (m.e. L^{-1})	0.18 to 8.69	2.45	0.05 to 12.04	1.44
SO_4^{2-} (m.e. L^{-1})	0.0 to 4.03	0.72	0.0 to 3.63	0.67
Ca^{2+} (m.e. L^{-1})	0.28 to 13.61	3.18	0.20 to 16.22	2.83
Mg^{2+} (m.e. L^{-1})	Nil to 4.53	0.44	Nil to 4.81	0.41
Na^+ (m.e. L^{-1})	0.16 to 49.34	8.19	0.16 to 59.69	9.12
K^+ (m.e. L^{-1})	0.02 to 0.21	0.07	0.03 to 0.24	0.05
F^+ (mg L^{-1})	Nil to 8.0	1.4	Nil to 12.0	1.52
RSC (m.e. L^{-1})	Nil to 14.52	4.9	Nil to 15.23	6.27
SAR (mmol $L^{-1})^{1/2}$	Nil to 23.26	8.1	Nil to 24.47	9.40
Water Table (m)	11 to 24	19	10 to 26	21

Table 2. Characteristics of the soils irrigated with tube well/open well waters

Characteristics	Uniara	Mean	Niwai	Mean
pH_2	7.73 to 9.61	8.04	7.53 to 9.44	7.91
EC_2 (1:2) (dS m^{-1})	0.26 to 2.78	0.68	0.18 to 1.89	0.45
HCO_3^- (m.e. L^{-1})	0.56 to 4.75	2.42	0.26 to 3.95	2.08
CO_3^{2-} (m.e. L^{-1})	0.41 to 3.89	1.67	0.33 to 3.05	1.36
Cl^- (m.e. L^{-1})	0.26 to 2.40	0.75	0.08 to 2.17	0.40
SO_4^{2-} (m.e. L^{-1})	Trace to 0.39	0.15	Trace to 0.22	0.11
Ca^{2+} (m.e. L^{-1})	0.62 to 1.16	0.78	0.41 to 1.05	0.77
Mg^{2+} (m.e. L^{-1})	0.18 to 0.75	0.41	0.12 to 0.68	0.29
Na^+ (m.e. L^{-1})	0.42 to 9.18	4.80	0.37 to 8.93	3.35
K^+ (m.e. L^{-1})	0.11 to 0.37	0.22	0.18 to 0.51	0.31
SAR (mmol $L^{-1})^{1/2}$	1.06 to 9.64	5.66	1.01 to 9.15	4.95
Sand (%)	24 to 49	32	52 to 65	56
Silt (%)	21 to 42	30	21 to 38	32
Clay (%)	24 to 28	27	11 to 20	17
Soil Texture	Clay loam		Sandy loam	

and highly alkali categories in Newai PS area, respectively as suggested by Gupta *et al*. (1994) (table 3). It was further observed that underground waters of Newai PS are HCO^{3-} > Cl^- > CO_3^{2-} > SO_4^{2-} type in respect of cations and Na^+ > Ca^{2+} > Mg^{2+} > K^+ in respect of anions. Correlation studies revealed that water table significantly and positively correlated with EC, SAR and RSC of irrigation water (r= 0.612**, 0.633** and 0.705**). Similarly water table was also significantly and positively correlated with fluoride content (r= 0.625**) in underground water.

Surface samples were also collected from the fields irrigated with corresponding waters and ranges of their chemical characteristics are given in table 2. The soils of Uniara PS area is under clay loam in texture. It was observed that pH varied from 7.73 to 9.61, EC from 0.26 to 2.78 dS m^{-1} and SAR from 1.06 to 9.64 with corresponding mean values 8.04, 0.68 dS m^{-1} and 5.66, respectively. In general all the values of anion and cations were higher in comparison with sandy loam soil because of clay loam soil have containing higher amount of clay particles. Correlation studies of soils of command area showed that EC of soil is significantly and positively correlated with EC of irrigation water (r = 0.612**). Similarly correlation between SAR of irrigation water and SAR of soil is found significantly and positively correlated (r = 0.529**). Similarly, soil pH was also significantly and positively correlated with sodium, carbonate and bicarbonate of underground irrigation water. Lal *et al.* (1998) also found significant positive correlation with EC and SAR of soil with EC and SAR of irrigation water in light textured soil.

The majority of soils of Newai PS area under are sandy loam in texture (table 2). It was observed that pH varied from 7.53 to 9.44, EC from 0.18 to 1.89 dS m^{-1} and SAR from 1.01 to 9.15 with corresponding mean values 7.91, 0.45 dS m^{-1} and 4.95, respectively. In general all the values of anion and cations were observed lower in comparison with clay loam texture soil. Correlation studies of soils of command area showed that EC of soil is significant and positively correlated with EC of irrigation water (r = 0.714**). Similarly correlation between SAR of irrigation water and SAR of soil is found significant and positively correlated (r = 0.630**). Soil pH was also significantly and positively correlated with sodium, carbonate and bicarbonate of underground irrigation water. Lal *et al*. (1998) also found significant positively correlation with EC and SAR of soil with EC and SAR of irrigation water in light textured soil

Conclusions

Problematic soil in semi arid region is created due to indiscriminate application of irrigation with poor quality under-ground water. A survey indicated that 37.1, 4.3, 24.3, 20.0 and 15.7 percent water samples were found under good, marginally saline, marginally alkali, alkali and highly alkali categories in Uniara PS, whereas 25.6, 8.6, 2.9, 28.6, 24.3 and 14.3 percent water samples were under good, marginally saline, saline, marginally alkali, alkali and highly alkali categories in Newai PS, respectively. 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 pearlmillet 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.

Table 3. Villages under different categories of quality in Tonk district

Water quality	Villages	Percentage
Uniara panchayat samiti		
1. Good (EC <2 dS m^{-1}, SAR < 10 & RSC < 2.5 mmol L^{-1})	Raipura, Balapura, Laxmipura, Binjari, Vijaynagar, Manoharpur, Sindoli, Hanotia, Panchala, Pancholi, Firozpur, Madanpur, Barana, Hamirpur, Mallapura, Shhpurkala, Karbadiakhas, Nababganj, Najeerpura, Shop, Padali, Kumharia, Mahuva, Binjari, Bhimganj, Banetha	37.1
2. Marginally saline (EC 2-4 dS m^{-1}, SAR < 10 & RSC < 2.5 m. e. L^{-1})	Ranipur, Kishanpur, Manpur,	4.3
3. Marginally alkali (EC < 4 dS m^{-1}, SAR < 10 & RSC 2.5-4.0 m. e. L^{-1})	Udaipur, Bhankarwadi, Ramnagar, Hardattpura, Chitani, Bosaria, Samrawata, Roopwas, Bhojpura, Bilaspur, Khatoli, Raghunathpurkala, Yakkobpur, Shyorajpur, Devari, Uniara, Gandoli	24.3
4. Alkali (EC < 4 dS m^{-1}, SAR < 10 & RSC > 4.0 m. e. L^{-1})	Nahra, Sendari, Thikaria, Palai, Sardarpur, Gangoli, Ukhlana, Devpur, Hingonia, Sitarampur, Ramganj, Chhatarpur, Fatehganj, Shripura	20.0
5. Highly alkali (EC variable, SAR > 10 & RSC < 4.0 mmol L^{-1})	Khedali, Kairod, Nahra, Sonthda, Gothda, Bhagawanpura, Patoli, Aligarh, Allapura, Jainagar, Dobadia	15.7
Niwai panchayat samit		
1. Good (EC <2 dS m^{-1}, SAR < 10 & RSC < 2.5 mmol L^{-1})	Akodia, Hanotia, Rajawas, Kibada, Jhilay, Sirohi, Palai, Sindada, Jugapura, Aliabad, Sajia, Sunari, Hanotia, Luhara, Bidoli, Bahakwa, Bidoli, Dangarthal	25.7
2. Marginally saline (EC 2-4 dS m^{-1}, SAR < 10 & RSC < 2.5 m. e. L^{-1})	Badagaon, Ramnagar, Dahalod, Khandewat, Kerond, Sunari	8.6
3. Saline (EC > 4 dS m^{-1}, SAR < 10 & RSC < 2.5 m. e. L^{-1})	Siras, Sindra	2.9
4. Marginally alkali (EC < 4 dS m^{-1}, SAR < 10 & RSC 2.5-4.0 m. e. L^{-1})	Sunara, Dayalpur, Nangal narhar, Turkia, Dheerajpura, Jasodanandpur, Badrampur, Laxmipura, Hingonia, Pahadi, Natwda, Shyosinghpura, Bherupura, Jeevali, Kariria, Jamdoli, Mendarkala, Maharajpur, Roopbas	28.6
5. Alkali (EC < 4 dS m^{-1}, SAR < 10 & RSC > 4.0 m. e. L^{-1})	Dangarthal, Chhorpura, Niwai, Chhainpura, Jaisinghpura, Mundia, Bhurtiakhurd, Bhanwata, Shrisukhpura, Bhagatrampur, Sendaria, Baradi, Bichpadi, Khidagi, Kanesar, Chhoria, Bad Chhoria	24.3
6. Highly alkali (EC variable, SAR > 10 & RSC < 4.0 mmol L^{-1})	Lodheda, Banasthali, Haripura, Dhani Jagatpure, Jagatpura, Bhagatrampur, Tumbipura, Suria, Harbagatpur, Shrikripalpur,	14.3

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References

Chesnin, L. and Yein, C.H. 1950. Turbidimetric determination and available sulphate. *Soil Science Society of America Proceedings* **15:** 149-151.

Dhir, R.P. and Singh, K.S. 1985. Soils of Rajasthan and their management. *Soils of India and Their Management*. Biswas, B. C., Yadav, D. S. and Mheshwari, S. (Ed.). Pub. The Fertilizer Association of India, New Delhi. pp. 343-364.

Gupta, Raj K., Singh, N.T. and Sethi Madhurima. 1994. *Water quality for irrigation in India. Tech. Bull*. 19, CSSRI, Karnal, p. 6.

Lal, P., Verma, V.L., Singhania, R.A. and Sharma, Y. 1998. Quality of underground irrigation waters of Bikaner district of Rajasthan and their effect on soil properties. *J. Ind. Soc. Soil Sci*. **46:** 119-123.

Piper, C.S. 1942. *Soil and Plant Analysis*. University of Adelaide, South Australia.

Richards, L.A. (Ed). 1954. *Diagnosis and improvement of saline and alkali soil*. USDA. Handbook No. **60**.

Yadav, H.D. and Kumar, Vinod. 1995. Management of sodic water in light textured soil. *Reclamation and management of water logged soils.* (Rao, KVGK, Agrawal, M.C., Singh, O.P. and Osterbaan, R.J. eds) pp. 226-241.

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Soil resource information and alternative crop planning for Ghaggar plain in North-Eastern parts of Patiala district (Punjab)

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ABSTRACT

A study was carried out of ten typical pedons representing soil profiles selected from different four landforms viz. Ghaggar flood plain, old flood plain with concave relief, recent flood plain and dissected upland using LANDSAT-LISS III satellite data and survey of India Toposheets in Patiala, Rajpura and Derabassi tehsils of Patiala district (Punjab) on 1:50,000 scale. The soils developed from sediments and originated from Siwalik Hills transported by the Ghaggar River. The major soils were very deep, neutral to strongly alkaline (6.4 to 9.0), medium in organic carbon, loamy sand to silty clay/clayey, with CEC low to medium (2.2 to 30.2 cmol (p+) kg^{-1}. The soils are medium in available nitrogen and potassium and low to medium in P status. The available micronutrients (DTPA extractable zinc, copper, iron and manganese) in the soil were adequate. Soils of old Ghagghar flood plains are dominated by Typic Haplustepts and Fluventic Haplustepts, whereas soils of old alluvial plain with concave relief are Aeric Epiaquepts, Aeric Endoquepts and Vertic Haplustepts. Soils on recent flood plains are classified as Typic Ustifluvents and Fluventic Haplustepts.Likewise the soils of dissected upland are dominated by Typic Ustifluvents and Typic Ustipsamments. The soils of study area have categorized on the basis of land capability classes II to VI. Their suitability have also been evaluated for major kharif and rabi crops and found that most of the plains soils are suitable to moderately suitable for rice, wheat, maize, mustard, sugarcane and chickpea, whereas soils of dissected upland having coarser texture are unsuitable for crops due to limitations of varying slopes, severe erosion, strongly alkaline pH and they requires conservation measures like contour bunding, check dams and gully plugging. They are better suited to agro-forestry, silvi-pastoral, silvi-horticulure or silvi-culture. The coarse textured soils in plain areas may be put under fodder, vegetables and oilseeds instead of rice. Fine loamy and fine soils having impeded drainage are suitable for rotational crops which can be grown on residual moisture or requiring minimum irrigation like barley, mustard, pulses etc. Sugarcane may also be grown in these soils. Class II land, all crops can be grown but the soil health is reduced due to continuous rice-wheat cropping system and poor quality of underground water. In order to maintain soil health legume crops should be introduced.

***Key words**:* cambic horizon, Silvi pastoral, land capability classification, land use plan, Soil suitability

Introduction

Land resources are under its-intensive pressure due to constant increase in human and livestock population with the result of over exploitation, resulting rapid degradation (Velayuthum and Bhattacharya 2000). The degradation is more acute in Indo-Gangetic plains of Punjab due to continuous rice-wheat cropping system and imbalance use of fertilizers and assorting to over exploitation of ground water. With a view, to maintain high production potential in the state, it is important to maintain environmental and soil quality on sustainable basis. The soils are varying inheritance properties and then responses to their management. Keeping, this in view, the soil resource inventory of area, a semi detailed survey was done on 1:50,000 scale to know the problems, potentials for preparing a plan of their uses on sustainable basis.

Materials and methods

The study area lies between $30^0 0'30''$ to $30^0 42'$ N latitudes and $76^0 17'$ to $76^0 56'$ E longitudes covering total area of about 2.28 lakh ha spread throughout Patiala, Rajpura and Derabassi tehsils of the Patiala district. This area is surrounded by Fatehgarh Sahib in north, Rupnagar district in north-east, Haryana in the south and east district and Nabha and Samana tehsils of the Patiala district. The climate of the district is semi arid monsoonic with severe summer and winter. The Length of growing period of crops ranges from 120 to 180 days. The mean annual temperature is 24.5^{0}C with mean summer and winter temperature of 31^{0}C and 16.3^{0}C, respectively. The mean annual precipitation is 900 mm in the area. The geology of the area is alluvium and sedimentary beds of the Siwaliks which Tertiary in origin and transported by the river Ghaggar. The sediments consist of clay, silt and sand with boulders, which belong to different periods. The natural vegetation consists of trees, shrubs and herbs. Common among the trees are *Dalbergia sissoo* (Shisham), *Morus alba* (Mulbery), *Azadirichta indica* (Neem), Melia azadircta (Dek), *Acacia arabica* (Babul), Zizphus jujube (Ber) and Butea monosperma (Dhak), shrubs like Zizyphus nummularia (Jharberi), *Lantana camera* (Lantana) and) and grasses like Munj (*Saccharum munja*), Kans (*Saccharum. spontaneum*), Cyprus rotundus (Motha) and Dub (*Cynodon dactylon*).

A semi detailed soil survey was conducted in the area as per procedure outlined by AIS&LUS (1970) and Sehgal *et al.* (1987) on 1:50,000, scale using LANDSAT-LISS III satellite data and Survey of India Toposheets, considering the various image characteristics like tonal variation, texture, shape and size of features. Four major landform units were delineated based on visual interpretation, viz., Ghaggar flood plain, old flood plain with concave relief, recent flood plain and dissected uplands**.** The ground truth data in respect of soil and land use were collected during the field visit of each physiographic unit through studies of mini pits and profiles for their morphological characteristics (Soil Survey Staff 1966 and Sehgal *et al.* 1987). The soil samples from each horizon of the representative pedons of the identified series were collected for morphological, physical and chemical properties. About two hundred surface soil samples (0-20cm) of grids at 2.5 km interval were also collected for soil fertility analysis. The collected samples were analyzed for physical and chemical properties using standard analytical techniques (Black 1965 and Jackson 1973).

Ten pedons were studied in detail and their morphological characteristics are presented in (table 1). The soil were correlated, classified (Soil Survey Staff 2006) and evaluated for land capability (Kligebiel and Montgomery 1961). Considering the potentials and limitations of the soils, sustainable management and conservation measures were suggested. Land capability classification up to sub group level (Klngebiel and Montgomery 1961) and soil suitability evaluation was based on soil site characteristics and crop requirement for major kharif crops (rice, maize and pearl millet) and rabi crops (wheat, mustard and chickpea worked out using suitability criteria (Sys *et al.* 1991 ; Sehgal 2005) with some modifications. Considering limitations and potentials of the soils, a suitable land use plan has also been suggested.

Results and discussion

Soil morphology

The soils of the area are very deep and poorly to excessively drained. The colour of soils on very gently to gentle slopes (3-8%) varied from dark brown to brown(7.5YR 3/4 to 4/4M) and on nearly level slopes (0-1%) from dark gray to dark yellowish brown (10YR 4/1 to 4/4M) with fine medium distinct to coarse prominent brown mottles (7.5YR 4/2- 4/4). The different soil colours appear to be part of the function of chemical and mineralogical composition as well as textural makeup of the soils and conditioned by topographic positions and moisture regime (Walia and Rao 1997). The soils of the study area showed a wide textural variation (sandy to clayey) which might be due to variation in topography and translocation of clay. The structure of the soil is sub angular blocky to single grain. The single grain structure of Bijanpur (P9) soils was due to inert nature of parent material. Pedon P1 to P5 had cambic (Bw) subsurface diagnostic horizons. Whereas, other pedons (P6, P7, P9 and P10) have no diagnostic subsurface horizons. Soils of old Ghagghar flood plains are well to moderately well drained, redder in colour, fine textured more stabilized and comparatively well developed and are dominated by Typic Haplustepts and Fluventic Haplustepts. In soils of old alluvial plain with concave relief soils are poorly to imperfectly drained, light olive brown to dark brown, fine to fine loamy having cambic and calcic sub surface horizons and classified as Aeric Epiaquepts, Aeric Endoquepts and Vertic Haplustepts. Soils on recent flood plains are well to moderately well drained, brown to dark yellowish brown, coarse textured and stratified and having cambic or lacking diagnostic horizon and classified as Typic Ustifluvents and Fluventic Haplustepts. Whereas soils of dissected upland are excessively drained, brown to dark yellowish brown, loamy to sandy loam with moderate to steep slope, eroded and degraded and lack of diagnostic subsurface horizons and are Typic Ustifluvents and Typis Ustipsamments.

Physical and chemical characteristics

Sand and silt constitute major part in these soils (table 1) and clay varied from 3.8 to 66%. Silt and sand were irregularly distributed with depth which may be due to litho logical discontinuity (Bhaskar *et al*. 2004) as in Pedon 6, P7 & P10. The ratio of clay to clay plus silt shows slight increase with depth in all pedons. This suggests an increasing degree of weathering and clay translocation from the upper layers (Ogunwale and Ashaye 1975; Virgo and Holmes 1977). More or less decrease in clay content with depth was noticed in pedon 7 and 9, which might be due to irregular deposition of alluvium.

The P8 and P9 soils were neutral to mildly alkaline (pH 6.4 to 7.8), P2, P4 and P7 mildly to moderately

Table 1. Morphological, Physical and Chemical Properties of Soils

Horizon	Depth (cm)	Colour (moist)	Mottles	Structure	Sand	silt (%)	clay	Clay/ (Silt+Clay)	pH (1:2.5)	EC (dSm^{-1})	O.C.	$CaCO_3$ (%)	CEC [cmol (p+) kg^{-1}]	B.S. (%)
Ghanaur (P1): Fine,mixed (calcareous),hyperthermic Typic Haplustepts														
Ap	0-15	7.5YR4/3	-	massive	18.7	43.0	38.3	0.47	8.7	4.0	1.00	2.37	18.6	98
AB	15-30	7.5YR4/4	-	m2sbk	18.2	42.8	39.0	0.48	8.7	3.4	0.52	1.14	19.8	96
Bw1	30-48	7.5YR3/4	-	m2sbk	15.9	43.6	40.5	0.48	8.6	3.7	0.44	1.14	20.0	96
Bw2	48-72	7.5YR3/4	-	m2sbk	8.5	50.3	41.2	0.45	8.3	4.5	0.42	2.56	20.6	96
Bw3	72-111	7.5YR3/4	-	m2sbk	7.1	50.4	42.5	0.46	8.1	4.2	0.33	3.32	20.8	97
Bw4	111-140	7.5YR3/4	-	m2sbk	10.3	48.0	41.7	0.46	8.0	3.3	0.29	3.32	20.8	98
Bw5	140-158	7.5YR3/4	-	m2sbk	18.0	39.3	42.7	0.52	7.9	3.4	0.25	1.52	21.0	99
Manakpur (P2): Fine, mixed, hyperthermic Fluventic Haplustepts														
AP	0-18	7.5YR4/3	-	massive	35.5	39.2	25.3	0.39	7.4	0.76	0.52	-	12.3	78
AB	18-35	7.5YR4/3	-	m2sbk	25.1	40.4	34.5	0.46	7.9	0.36	0.30	-	16.5	71
Bw1	35-63	7.5YR4/4	-	m2sbk	18.6	45.9	35.5	0.44	7.8	0.31	0.24	-	16.5	73
Bw2	63-84	7.5YR3/4	-	m2sbk	17.2	40.8	42.0	0.51	8.0	0.26	0.22	-	18.6	73
Bw3	84-107	7.5YR4/4	-	m2sbk	17.0	40.9	42.0	0.51	8.0	0.25	0.22	-	15.6	86
Bw4	107-122	7.5YR4/3	-	m2sbk	19.7	40.9	39.4	0.49	8.0	0.27	0.32	-	17.1	78
BC	122-150	7.5YR3/4	-	m1sbk	18.1	45.6	36.3	0.44	8.1	0.38	0.20	-	18.2	73
Sadhu (P3):Fine, mixed (calcareous, hyperthermic Vertic Haplustepts														
Ap	0-18	10YR3/4	-	0-18	2.1	39.0	58.2	0.60	8.6	2.6	1.03	1.89	26.0	92
AB	18-48	10YR4/4	-	18-48	2.8	39.5	57.7	0.59	8.8	2.70	0.49	1.53	26.6	92
Bw1	48-75	10YR4/4	-	48-75	3.1	38.6	58.3	0.60	8.6	3.10	0.37	1.89	28.0	92
Bw2	75-105	7.5YR4/4	-	75-105	1.5	39.0	59.5	0.60	8.6	4.50	0.23	2.97	28.0	92
Bw3	105-130	7.5YR3/4	-	105-130	5.3	33.4	61.3	0.65	8.4	4.80	0.37	1.80	28.5	91
Bw4	130-145	7.5YR3/4	-	130-145	4.0	29.1	66.0	0.69	8.6	7.90	0.37	1.62	30.2	96
Ranbirpura (P4): fine loamy, mixed (calcareous), hyperthermic Aeric Epiaquepts														
Ap	0-17	10YR4/1	-	massive	74.0	10.2	15.8	0.61	7.4	0.46	0.67	-	8.2	80
AB	17-38	10YR4/2	-	m1sbk	72.5	8.2	19.3	0.70	8.3	0.26	0.15	-	10.0	75
Bw1	38-61	10YR4/2	-	m1sbk	69.4	9.2	21.4	0.70	8.1	0.22	0.13	-	10.6	80
Bw2	61-81	10YR4/3	7.5YR4/2 c1d	m1sbk	64..3	13.0	22.7	0.64	8.2	0.22	0.19	-	10.8	78
Bw3	81-105	10YR4/3	7.5YR4/2c2p	m2sbk	38.0	28.3	33.7	0.54	8.0	0.17	0.06	-	13.5	74
Bw4	105-129	10YR4/3	7.5YR4/2c2p	m2sbk	35.6	30.6	33.8	0.52	8.0	0.23	0.03	-	13.5	79
BC	129-155	10YR4/3	7.5YR4/2c2p	m2sbk	52.6	23.1	24.3	0.51	7.9	0.19	0.02	-	10.8	81

contd...

Table 1 ***contd...***

Horizon	Depth (cm)	Colour (moist)	Mottles	Structure	Sand	silt (%)	clay	Clay/ (Silt+Clay)	pH (1:2.5)	EC (dSm^{-1})	O.C.	$CaCO_3$ (%)	CEC [cmol (p+) kg^{-1}]	B.S. (%)
Kahangarh (P5): Fine loamy, mixed (calcareous), hyperthermic, Aeric Endoaquepts														
Ap	0-18	10YR4/1	-	massive	38.1	36.4	25.5	0.41	8.3	0.69	0.95	6.17	12.0	78
Bw1	18-40	10YR4/2	-	m2sbk	22.9	43.6	33.5	0.43	8.6	0.74	0.53	5.89	18.5	74
Bw2	40-57	10YR4/2	-	m2sbk	28.5	33.5	38.0	0.53	8.5	0.62	0.45	2.85	19.0	77
Bw3	57-76	10YR5/2	7.5YR4/4f1d	m2sbk	51.0	21.0	28.0	0.57	8.4	0.43	0.20	2.37	14.5	86
Bw4	76-97	10YR4/1	7.5YR4/4f1d	m2sbk	44.2	23.7	32.1	0.58	8.4	0.37	0.20	2.56	15.5	90
Bw5	97-122	10YR4/1	7.5YR4/4f1d	m2sbk	55.6	20.4	24.0	0.54	8.3	0.29	0.20	2.56	12.5	97
Bw6	122-150	10YR4/1	7.5YR4/4f1d	m2sbk	62.0	11.4	26.6	0.70	8.2	0.24	0.20	3.04	13.0	95
Nagwan (P6): coarse loamy over fine silty, mixed(calcareous), hyperthermic Typic Ustifluvents														
Ap	0.17	10YR3/2	-	massive	57.4	25.6	17.0	0.40	8.4	0.98	0.13	2.66	9.0	94
2C1	17-36	7.5YR4/3	-	massive	65.7	21.9	12.4	0.36	8.1	2.30	0.79	2.56	6.8	93
3C2	36-50	7.5YR4/3	-	massive	72.2	12.8	15.0	0.54	8.8	1.01	0.10	2.09	7.0	99
4C3	50-82	10YR4/3	-	massive	90.1	6.1	3.8	0.38	8.8	0.69	0.08	2.85	1.6	72
5C4	82-108	7.5YR4/3	-	massive	11.9	56.7	31.4	0.36	8.7	1.10	0.25	4.27	15.8	81
5C5	108-125	7.5YR4/3	-	massive	15.9	51.4	32.7	0.39	8.7	1.30	0.25	2.37	16.2	85
5C6	125-160	7.5YR4/3	-	massive	17.6	51.8	30.6	0.37	8.8	1.20	0.25	4.56	14.8	83
Daun (P7): Coarse loamy over sandy, mixed (calcareous), hyperthermic Typic Ustifluvents														
Ap	0-15	7.5YR4/3		massive	56.1	34.4	9.5	0.22	7.8	1.10	0.56	3.81	4.2	94
A2	15-38	7.5YR4/4	-	massive	54.8	35.0	10.2	0.23	7.9	0.92	0.23	6.66	5.0	98
Ac	38-66	7.5YR3/4	-	massive	61.4	27.9	10.7	0.28	8.0	0.91	0.11	4.28	5.2	73
2C1	66-94	7.5YR4/4	-	massive	59.5	33.2	7.3	0.18	8.1	1.1	0.23	6.66	3.6	78
2C2	94-112	7.5YR4/4	-	massive	68.8	21.5	9.7	0.31	8.1	1.00	0.19	6.19	4.2	91
3C3	112-135	7.5YR4/4	-	massive	72.4	21.4	6.2	0.22	8.0	1.40	0.11	5.24	3.0	98
3C4	135-145	7.5YR4/4	-	massive	70.2	24.8	5.0	0.17	8.0	1.30	0.11	5.24	3.0	99
3C5	145-160	7.5YR4/4	-	Single grain	79.4	16.1	4.5	0.22	8.0	1.20	0.10	5.71	2.2	98
Janetpur (P8): coarse loamy, mixed, hyperthermic Fluventic Haplustepts														
Ap	0-16	10YR4/4	-	massive	66.1	14.5	19.4	0.57	7.6	0.76	0.50	-	9.5	77
Ap	16-34	10YR4/4	-	m2sbk	65.5	15.4	19.1	0.55	7.9	0.53	0.26	-	9.0	81
Bw1	34-54	10YR3/6	-	m2sbk	60.8	20.9	18.3	0.47	7.6	0.44	0.17	-	8.0	80
Bw2	54-80	10YR3/6	-	m2sbk	63.6	20.3	16.1	0.44	7.4	0.50	0.17	-	8.5	76
Bw3	80-100	10YR3/6	-	m2sbk	65.8	15.9	18.3	0.54	7.2	0.33	0.23	-	8.5	68
Bw4	100-120	10YR4/3	-	m2sbk	67.0	17.7	15.2	0.46	7.3	0.32	0.15	-	7.2	79
C	120-150	10YR4/3	-	massive	69.2	16.4	14.4	0.47	7.3	0.22	0.09	-	7.0	82

contd...

Table 1 ***contd...***

Horizon	Depth (cm)	Colour (moist)	Mottles	Structure	Sand	silt	clay	Clay/ (Silt+Clay)	pH (1:2.5)	EC (dSm^{-1})	O.C.	$CaCO_3$	CEC [cmol (p+) kg^{-1}]	B.S. (%)
					(%)						(%)			
Bijanpur (P9): mixed, hyperthermic Typic Ustipsamments														
Ap	0-10	7.5YR4/4	-	Single grain	82.1	8.4	9.5	0.53	7.1	0.60	0.17	-	4.8	75
A2	10-32	7.5YR4/4	-	Single grain	83.4	5.6	11.0	0.66	7.0	0.59	0.10	-	6.7	79
C1	32-50	7.5YR4/4	-	Single grain	83.4	7.1	9.5	0.57	6.9	0.55	0.10	-	7.2	86
C2	50-75	7.5YR4/4	-	Single grain	84.8	7.7	7.5	0.49	6.8	0.47	0.08	-	8.2	78
C3	75-90	7.5YR4/4	-	Single grain	89.8	6.4	3.8	0.37	6.4	0.49	0.08	-	8.8	78
C4	90-106	7.5YR4/4	-	Single grain	80.4	7.9	11.7	0.60	7.0	0.48	0.08	-	8.8	79
C5	106-155	7.5YR4/4	-	Single grain	86.5	7.6	5.9	0.44	7.0	0.42	0.06	-	8.5	79
Nibwa (P10):Coarse loamy, mixed (calcareous), hypwerhermic Typic Ustifluvents														
A	0-24	10YR4/3	-	Single grain	81.4	8.3	10.3	0.55	7.6	0.54	0.42	0.95	5.0	88
C1	24-45	10YR5/4	-	massive	47.4	35.1	17.5	0.33	9.1	1.50	0.08	4.30	7.8	81
C2	45-69	10YR5/4	-	massive	49.2	28.8	22.0	0.43	9.1	1.60	0.06	3.62	10.0	97
2C3	69-90	10YR5/4	-	massive	67.3	16.0	16.7	0.51	9.1	1.30	0.04	1.43	8.2	99
2C4	90-116	10YR5/6	-	massive	61.0	22.2	16.8	0.43	9.1	1.20	0.02	1.43	8.2	99
2C5	116-130	10YR5/6	-	massive	68.2	16.6	15.3	0.48	9.1	1.20	0.02	1.52	7.6	95
2C6	130-143	10YR5/6	-	massive	68.0	17.5	14.5	0.45	8.9	0.89	0.06	1.43	7.5	95
2C7	143-163	10YR5/6	-	massive	55.3	26.0	18.7	0.42	9.0	1.10	0.06	1.33	7.5	94

Where m1sbk- moderate weak subangular blocky,m2sbk- moderate medium suangular blocky, f1d- few fine distict,c1d-common fine distict,c2p- common medium distinct

Table 2. Available nutrients in surface soils

Soil Series	Available macronutrients (kg ha^{-1})			Available micronutrients (mg kg^{-1})			
	N	P	K	Zn	Cu	Mn	Fe
Ghanaur(P1)	275	18.5	285	1.38	4.09	40.00	15.00
Manakpur (P2)	252	15.5	222	0.63	1.53	39.36	39.80
Sadhu (P3)	295	22.2	290	0.61	2.75	18.12	38.00
Ranbirpura (P4)	260	12.3	245	1.53	2.23	22.94	26.20
Kahangarh (P5)	285	14.2	285	2.33	4.83	16.66	34.56
Nagwan (P6)	120	11.5	152	0.33	1.31	9.74	5.48
Daun (P7)	255	12.2	160	0.75	1.87	27.08	7.72
Janetpur (P8)	230	11.8	152	0.44	0.72	20.42	6.74
Bijanpur (P9)	100	11.5	115	0.95	1.12	17.06	28.00
Nibwa (P10)	120	12.0	125	1.05	0.59	9.20	5.84

alkaline (pH 7.4 to 8.3) in reaction. Whereas P1, P3, P5, P6 and P10 soils had moderately to strongly alkaline (pH 7.9-9.0) soil reaction. The organic carbon content of soils is medium to high in surface soils except in P3, P9 and P10 which have low in content. The organic carbon decreases with depth mostly in all the soils barring in P2, P3, P6 and P10 (Verma *et al.* 2012). The calcium carbonate ranged from0.95 to 6.66%. The calcium carbonate in P1 and P6 soils increased with depth might be due to illuviation along with clay. While P 2, P4, P8 and P9 soils were non calcareous in nature. The CEC of P1, P2, P3 and P5, varied from 12 to 30.2 cmol (p+) kg^{-1} which were higher than other pedons and their base saturation varied from 71 to 99%.

Available nutrients

The data (table 2) indicated that the majority of soils (P1-P5 and P7) were medium (252 to 295 kg ha^{-1}) in N content except P6, P8-P10 soils which having low (100 to 230 kg ha^{-1}) content of available N. The available P content varied from 11.5 to 22.2 kg ha$^{-1.}$ Majority of soils are low in available P except P1, P2, P3, P5 which had medium available P. This might be due to higher organic carbon, clay and low pH (7.9 to 8.7). The available K content varied from 115 to 295 kg ha^{-1} and most of the soils were rich in available K. Pasricha (2002) reported high K content in these soils owing to the presence of mica in fine silt and clay fractions.

The available Zn content of most soils were found adequate to high (0.75 to 2.33 mg kg^{-1}) except P2, P3, P6 and P8 which had low to marginal (0.33 to 0.63 mg kg^{-1}). Zinc availability is sensitive to soil pH and presence of free lime, clay and organic matter content of the soils (Sakal *et al.* 1988 and Khan *et al.* 1997).The DTPA extractable Cu ranged from 0.59 to 4.83 mg kg^{-1}, indicating that present source of alluvium is rich in Cu bearing minerals. The soils of the area were adequate to high in Cu except P8,P9 and P10 which had marginal to low in content (0.59 to 1.12 mg kg^{-1}), this might be due to sandy texture and low organic carbon content of the soil (Khan *et al.* 1997). Almost similar content of available Cu was also reported by Singh and Tripathi (1983). Available Fe content in the soils were mostly adequate to high except P6,P7,P8,P10 which had low to marginal iron and its content ranged from 9.20 to 39.8 mg kg^{-1}. The soils were rich in free lime, P and well to somewhat excessively drained and likely to suffer from Fe deficiency. The available manganese in these soils ranged from 9.2 mg kg^{-1} in P10 to 40 mg kg^{-1} in P1 soils. The data further revealed that the soils had adequate to high in available Mn except P6 and P10 which were deficient in manganese which might be due to coarser texture (Randhwa and Singh 1997).

Suitability of crops

Ten soils were evaluated for major kharif (Rice, maize) and rabi crops (wheat, mustard, chickpea, sugarcane, sunflower and potato) (table 3). Ghanaur (P1) soils are highly suitable for rice and moderately suitable for wheat, maize and mustard due to finer texture. Whereas sugarcane, potato, sunflower and chickpea were marginally suitable due to limitations of fine texture, prolonged water stagnation and slow permeability. The Manakpur (P2) soils are moderately suitable for wheat, maize, mustard and chickpea and highly suitable for rice, sunflower and potato due to finer texture and better drainage favours cultivation of these crops. Sadhu (P3) soils are moderately suitable for rice and wheat due to fine texture and marginally suitable for sugarcane, sunflower, mustard and unsuitable to potato, maize and chickpea due to imperfect drainage and strongly alkaline pH unfavourable for its cultivation. Ranbirpura (P4) soils are moderately suitable for all major kharif and rabi crops grown in the area and highly suitable to sunflower due to

Table 3. Soil suitability classes for major crops

Soil Series	Land capability subclass	Rice	Wheat	Maize	Sugarcane	Potato	Mustard	Sunflower	Chick pea
Ghanaur (P1)	IIsw	S1	S2	S2	S3	S3	S2	S3	S3
Manakpur (P2)	IIs	S1	S2	S2	S2	S1	S2	S1	S2
Sadhu (P3)	IIIsw	S2	S2	N	S3	N	S3	S3	S3
Ranbirpura (P4)	IIIw	S2	S2	S2	S2	S2	S2	S1	S2
Kahangarh (P5)	IIIsw	S1	S3	S3	S3	N	S3	S3	N
Nagwan (P6)	IIsw	S2	S2	N	S2	S3	S2	S3	S3
Daun (P7)	IIs	S2	S2	S2	S2	S2	S1	S2	S2
Janetpur (P8)	IIS	S3	S2	S2	S2	S2	S2	S2	S2
Bijanpur (P9)	Ives	N	S3	S3	S3	N	S3	N	S3
Nibwa (P10)	Vies	S3	S3	S3	N	N	S3	N	S3

Where S1- Highly suitable, S2-Moderately suitable, S3 marginally suitable and N-Unsuitable

fine loamy texture and stored moisture in rabi season. Kahangarh (P5) soils are highly suitable for rice due to fine texture and hydromorhic conditions favours cultivation of these crops. This soil is marginally suitable to wheat, sugarcane, mustard and sunflower and unsuitable for potato and chickpea. Nagwan (P6) soils are moderately suitable for rice, wheat, sugarcane, mustard and unsuitable for maize and marginally suitable for potato, sunflower and chick pea because of limitations of wetness and moderate to strongly alkaline pH. Daun (P7) soils are moderately suitable for all crops but highly suitable for mustard due to medium in nutrients status. Janetpur (P8) soils are moderately suitable for all crops except rice which is marginally suitable due to lighter texture and droughtiness. Bijanpur (P9) soils are marginally suitable for wheat, maize, sugarcane, mustard and chick pea while unsuitable for rice, potato and sunflower due to limitations of coarse texture, excessive drainage, moderate erosion, droughtiness, low AWC and poor nutrient retention. These soils are suitable for silviculture and agro forestry. Nibwa soils are marginally to unsuitable for crops with limitations of steep slope, excessive drainage, severe erosion and salinity and sodicity hazards. They are better suited to social forestry, silvi-pastoral and silvi-horticulture.

Land capability classification and suggested land use planning

The land capability classification (Klingebiel and Montgomery 1961) is an interpretative grouping of different soil units into different classes based on their limitations and potentials serves as guide to assess soil suitability of the lands for cultivation, grazing and forest plantation. The grouping of soils into capability classes based on the severity of limitations viz., erosion risk (e), wetness (w), rooting zone, soils (s), and climatic limitations (c). The soils of the study area were classified into six land capability subclasses for better management of lands. The P2, P7 and P8 soils had placed under land capability class IIs, P1 and P6 were grouped in IIsw. Pedon P3 and P5 were placed in IIIsw. Whereas pedon P4, P8 and P9 alone had been put in IIIw, IVes and VIes, respectively. The detailed description of land capability classes with potentials, limitations and suggested land use is given in table 4. By adopting suggested land use in the respective areas, sustained crop production can be achieved as it helps in the conservation of soil and water besides the improvement of physical properties of soils.

Conclusions

The study of morphological, physical and chemical properties of soils revealed that the soils of Patiala-Rajpura and Derabsssi area were neutral to strongly alkaline in soil reaction, medium to high in organic carbon. The CEC of soils varied from low to medium and exchange complex was dominated by Ca^{2+}.These soils are medium in available nitrogen and potassium and low to medium in P status. Further, the soils were adequate in available zinc, copper, iron and Mn status. Soils of the area have been classified up to series level. The coarse loamy and sandy soils which are highly eroded and degraded and marginally to unsuitable for crops might be put under agro forestry, silvi pastoral or silviculture. The coarse textured soils in plain areas are suitable for growing fodder, vegetables and oilseeds instead of rice. Fine loamy and fine soils having impeded drainage may be rotated with crops which can be grown on residual moisture or requiring minimum irrigation like barley, mustard, pulses etc. Sugarcane may also be grown in these soils. Class II land, all crops can be grown but soil health has to be reduced due to continuous rice-wheat cropping system and poor quality of underground water. In such

Table 4. Interpretation of soils for land use planning

Soil Series	LCC	Description	Major limitations	Suggested land use
Ghanaur (P1)	IIsw	Good cultivable land for sustainable agriculture.	Moderate problem of water stagnation, cracking in summers and slow permeability due to low relief.	Rice may be rotated with crops like mustard, lentil, berseem, in addition to wheat or rice may be rotated with wheat plus mustard crops.
Manakpur (P2)	IIs	Very good cultivable land for sustainable agriculture.	Very good soils and under intensive cultivation, however, slight problem of nutrients, formation of sub surface hard layer due to rice cultivation, slow drainage due to construction of roads, fine textured soils, formation of clods and ground water depletion.	Soils are ideal to grow all climatically adapted crops like rice, wheat, sugarcane, maize, and mustard with inclusion of legumes (chickpea) in crop rotation.
Sadhu (P3)	IIIsw	Good cultivable land for sustainable agriculture.	Fine textured soils, formation of clods, low soil permeability, ground water depletion and deep cracking in summers, slow surface drainage.	Soils are suitable for cultivation of all climatically adapted crops. Rice and wheat are the most suitable but maize, mustard, pearl millet and chick pea must be included in crop rotation.
Ranbirpura (P4)	IIIw	Moderately good cultivable land for cultivation.	Fine loamy soils but choice of crops restricted due to excessive wetness, water logging, and stagnation of water in rainy season, low to moderate soil fertility.	Rice in kharif may be rotated with wheat, mustard, sunflower which are suitable to moderately suitable in rabi season other crops like chick pea, potato, sugarcane are also suitable.
Kahangarh (P5	IIIsw	Moderately good cultivable land for sustainable agriculture.	Poorly drained and poor aeration, water stagnation in rainy season and low to moderate nutrient retention.	Suitable for rice in rainy season and rotated with wheat and mustard in rabi season when upper 50cm free of wetness
Nagwan (P6)	IIsw	Moderately good cultivable land for sustainable agriculture.	Occasional flooding water stagnation during rainy season, crust formation, low nutrient retention and slight problem of salinity moderate to strongly alkaline and coarse textured soils.	Rice may be rotated with sugarcane or wheat and mustard.
Daun (P7)	IIs	Good lands for sustainable agriculture	Excessively drained, coarse texture with sandy strata, low in AWC and poor nutrient retentivity	Suitable for all climatically adopted crops with addition of FYM and proper of soils water conservations Fit for mustard in rabi & vegetable in winter season.
Janetpur (P8)	IIS	Good land for cultivation of crops	Coarser texture, somewhat high permeability, slight erosion, droughtiness, poor in soil fertility and low in organic matter content.	Soils are moderately suitable for all climatically adopted crops except rice with addition of organic matter or green manuring and with soil and conservation measures.
Bijanpur (P9)	IVes	Fairly good cultivable land and better for grazing and forestry.	Low available water capacity, poor soil fertility and susceptible to mod erosion, droughtiness, poor in nutrient and water retention	Soils are marginal or unsuitable for cultivation of crops but they can be suitable for agro forestry, silviculture and silvi-pastoral.
Nibwa (P10)	VIes	Unsuitable for cultivation of crops and good for grazing or forestry.	Sandy textured, rapid permeability, very severe erosion/gullied, droughtiness, rapid runoff, steep sloppiness, poor in soil fertility and low in organic matter content, sodic soils and high lime, low hydraulic	Soils are unsuitable for crops and are suitable to silvi-pastoral, silvi-horticulture culture and silvi pasture and social forestry.

soils legume crops must be introduced to maintain soil health.

References

AIS&LUS. 1970. Soil Survey Manual, All India Soil and Land Use Survey Organization, IARI, New Delhi, p1-63.

Bhaskar, B.P., Saxena, R.K., Vaidivelu, S., Barua, U., Butte, P.S. and Dutta, D.P. 2004. Pedogenesis in high altitude soils of Meghalaya plateau. *Agropedology* **14:** 9-23.

Black, C.A. 1965. *Methods of Soil Analysis*, Part 2, *American Society of Agronomy*, Inc., Madison,Wisconsin, U.S.A.

Jackson, M.L. 1973. *Soil Chemical Analysis*, Prentice Hall of India Pvt. Ltd., New Delhi, India.

Khan, J.H., Majumdar, A.R., Hussain, M.S. and Mohiuddin, A.S.M. 1997. Total DTPA-Extractable Fe, Mn, Cu, and Zn contents in some soils of Bangladesh. *Journal of the Indian Society of Soil Science* **45(3):** 485-489.

Klngebiel, A.A. and Montgomery, P.H. 1961. *Land Capability Classification*, Agricultural Hand book No. 210, USDA, Washington, D.C.

Ogunwale, J.A. and Ashaye, T.I. 1975. Sandstone derived soils of a catena of Iperu, Nigeria. *J. Soil Sci.* **26:** 22-32.

Pasricha, N. S. 2002. Potassium dynamics in soils in relation to crop nutrition. *Journal of the Indian Society of Soil Science* **50(4):** 333-344.

Randhawa, H.S. and Singh, S.P. 1997. Distribution of Manganese fractions in alluvium derived soils in different agro climatic zones of Punjab. *Journal of the Indian Society of Soil Science* **45(1):** 53-57.

Sakal, R., Sinha, A.P. and Singh, S.P. 1988. Distribution of available zinc, copper, iron and manganese in old alluvial soils as related to certain soil Character. *Journal of the Indian Society of Soil Science* **36:** 59-63.

Sehgal, J.L. 2005. Pedology: Concepts and Applications, Second revised and expanded edition, Kalyani Publishers, New Delhi.

Sehgal, J.L., Saxena, R.K. and Vadivelu, S. 1987. Soil Resource Mapping of Different States in India. Tech. Bull, 13, NBSS&LUP, Nagpur.

Singh, V. and Tripathi, B.R. 1983. Available micronutrient status of citrus growing soils of Agra region. *J. Indian Soc. Science* **31:** 310-312.

Soil Survey Staff 1966. Soil Survey Manual, Agric. 18, Indian reprint, Oxford & IBH Pub. Co., New Delhi.

Soil Survey Staff. 2006. *Keys to Soil Taxonomy*, Seventh Edition. (U.S.D.A.: Washngton, D.C.).

Sys, Ir. C., Van Ranst, E. and Debaveye, Ir. J. 1991. Land Evaluation (Part I-III), Agricultural Publication No.7, Central Administration of Development Cooperation, Brussels, Belgium.

Velayuthum, M. and Bhattacharya, T. 2000. Soil Resource management. In: *Natural Resource Management for Agricultural Production in India* (Eds. J.S.P.Yadav and G.B. Singh) pp. 1- 136.

Virgo, K.J. and Holmes, D.A. 1977. Soils and landform features of mountainous terrain in South Thailand. *Geoderma* **18:** 207-225.

Walia, C.S. and Rao, Y.S. 1997. Characteristics and classification of some soils of Trans-Yamuna plains. *Journal of the Indian Society of Soil Science* **45:** 156-162.

Verma, T.P., Singh, S.P., Ram Gopal, Dhankar, R.P., Rao, R.V.S. and Tarsem Lal. 2012. Characterization and evaluation of soils of Trans Yamuna area in Etawah district, Uttar Pradesh for sustainable land use. *Agropedology* **22(1):** 26-34.

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Performance of soybean under partially reclaimed sodic Vertisols

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ABSTRACT

A field experiment was conducted in randomized block design with three replications during *Kharif* 2010 and 2011 at RVSKVV Salinity Research Farm, Barwaha, district Khargone, Madhya Pradesh to study the performance of soybean under partially reclaimed sodic Vertisols. The results of the experiment showed that number of pods/plant, number of seeds/pod and test weight was maximum with the application of spent wash @ 10.0 lakh L ha^{-1}, though these were at par with the application of 5.0 lakh L ha^{-1} spent wash during both years. The application of spent wash @ 5.0 lakh L ha^{-1} produced significantly higher seed (2.14 and 2.45 t ha^{-1}) and straw (2.74 and 3.00 t ha^{-1}) yield of soybean over other treatments. Application of spent wash @ 10.0 lakh L ha^{-1} produced at par seed and straw yields. The results showed that application of spent wash can be used as an alternate source for reclamation of sodic lands.

Key words: FYM, Gypsum, sodic Vertisols, spent wash, vermicompost

Introduction

The salt affected soils are estimated about 6.73 million ha in the country. (Mandal *et al.* 2010). Out of which 2.42 lakh ha is found in Madhya Pradesh (Sharma, 1996). In black soils (Vertisols) the main problem is of sodicity. Soil sodification induces higher swelling and water retention. The reclamation and utilization of sodic lands are of prime importance in view of the ever increasing population pressure for demand of food grains. Gypsum is one of the most effective amendments for reclamation of sodic soils. But due to limited availability of mined gypsum, use of alternate sources is the need of the hour. Spent wash contains sufficient amount of calcium, sulphur and other essential nutrients along with organic carbon. It is acidic in nature which might be helpful in faster amelioration of sodic soils. The reclamation of sodic soils basically requires the removal of excess sodium from the exchange complex with calcium and the replaced sodium leached out of root zone. Amendments, particularly the acid formers like sulphur, pyrites, ferrous sulphate and sulphuric acid recommended for reclamation of sodic soils appeared to be very expensive and not easily available locally and are difficult in handling under field conditions. Gypsum is the cheapest and most convenient amendments used for reclamation of sodic soils. But now-a-days the availability of gypsum is scared and hence there is a need to find out alternate amendments. Spent wash (a distillery effluent) is an organic material, highly acidic in reaction with high BOD, COD and contains calcium, magnesium, potassium and sulphur in sufficient amounts. This might be better preposition for reclamation of sodic Vertisols. Sindhu *et al.* (2007) reported that the high concentration of Ca and Mg in spent wash may have potential in reclaiming the sodic soils similar to that of gypsum effect. The present study was undertaken to evaluate the performance of soybean under partially reclaimed sodic Vertisols.

Materials and methods

The experiment was conducted in randomized block design with nine treatments and replicated thrice during *kharif* season of 2010 and 2011 at Salinity Research Station, Barwaha (Khargone) M.P. with soybean (var. 9305) as a test crop. The experimental soil belongs to fine montmorillonitic hyperthermic family of typic heplusterts (sodic phase). The soil was sodic Vertisols with pH 8.5, EC 1.4 dSm^{-1} and ESP 40. The treatments comprised of control, FYM @ 5 t ha^{-1}, vermicompost @ 5 t ha^{-1}, gypsum @75% GR, gypsum @75% GR + FYM @ 5 t ha^{-1}, gypsum @75% GR+ vermi-compost @ 5 t ha, spent wash @ 2.5 lakh L ha^{-1}, spent wash @ 5.0 lakh L ha^{-1} and spent wash @ 10.0 lakh L ha^{-1}. The treatments were applied once in a year during preceding three years (2007, 2008 and 2009) under paddy-wheat cropping sequence i.e. 30 days prior to transplanting of paddy seedlings for reclamation of sodic soils. The soybean crop was raised under same plots after three years without any treatment after reclamation. Soil ESP of the experimental plots before sowing of

Table 1. Soil ESP at the time of sowing of soybean crop

Treatments applied during reclamation process prior to soybean	Soil ESP
T_1 Control	35.1
T_2 FYM @ 5 t ha^{-1}	33.4
T_3 Vermicompost@ 5 t ha^{-1}	33.0
T_4 Gypsum @ 75 % GR	23.8
T_5 Gypsum @ 75 % GR + FYM @ 5 t ha^{-1}	23.0
T_6 Gypsum @ 75 % GR + Vermicompost @ 5 t ha^{-1}	21.6
T_7 Spent Wash @ 2.5 lakh L ha^{-1}	19.5
T_8 Spent Wash @ 5.0 lakh L ha^{-1}	16.9
T_9 Spent Wash @ 10.0 lakh L ha^{-1}	16.9

soybean crop is presented in Table 1. Recommended doses of nutrients were given as per the recommendations for sodic soils. The composition of spent wash, vermicompost and FYM are presented in Table 2 and 3. Spent wash, FYM and vermicompost were chemically analyzed using standard methods. Plant (seed and straw) samples collected at harvest, were air dried and then oven dried at 55° C. Samples were digested in di-acid mixture for analysis of P, K, Na, Ca and Mg. Total P was determined by vanado-molybdo-phosphoric yellow colour method (Chapman & Pratt, 1961). Total K and Na were determined by flame photometer. Ca and Mg were determined by versanate titration method. Total nitrogen in plant samples was determined by microkjeldahl method. Exchangeable sodium per cent of soil was estimated by the method as outlined by Richards (1954).

Results and discussion

Yield attributes of soybean

The yield attributes viz. number of pods/ plant, number of seeds/ plant and test weight of soybean increased significantly over control with the application of different treatments. Maximum number of pods, number of seeds and test weight was recorded with the application of spent wash @ 10.0 lakh L ha^{-1}, though these were at par with spent wash application of 5.0 lakh L ha^{-1} during both the years. The no. of pods/plant increased significantly with spent wash application upto 5 lakh L/ ha though the maximum was obtained with spent wash application of 10 lakh L/ha. The averaged data over two years showed that application of spent wash applied @ 2.5, 5.0 and 10 lakh L/ha increased the no. of pods/plant by 78.9, 95.9 and 104.3 per cent respectively over control. Application of gypsum @ 75%GR+FYM @ 5t/ha and gypsum @ 75%GR+vermicompost @ 5t/ha also results in significantly lower no. of pods/plant as compared to SW application @5 lakh L/ha during both the years. Similarly no. of seeds/pod also increased significantly with spent wash application upto 5 lakh L/ha though the maximum was obtained with spent wash application of 10 lakh L/ha. The averaged data over two years showed that application of spent wash applied @ 2.5, 5.0 and 10 lakh L/ha increased the no. of seeds/pod by 21.7, 35.8 and 38.4 per cent respectively over control. Application of gypsum @ 75%GR+FYM@ 5t/ha and gypsum @ 75%GR+vermicompost @ 5t/ha also results in significantly lower no. of seeds/pod as compared to SW application @5 lakh L/ha during both the years. In case of test weight, spent wash application results in significantly higher test weight upto 5 lakh L/ha though the maximum was obtained with spent wash application of 10 lakh L/ha. The averaged data over two years showed that application of spent wash applied @ 2.5, 5.0 and 10 lakh L/ha increased the test weight of soybean seeds by 12.9, 27.3 and 30.2 per cent respectively over control. Application of gypsum @ 75%GR+FYM@ 5t/ha and gypsum @ 75%GR+ vermicompost @ 5t/ha also results in significantly lower test weight as compared to spent wash application @ 5 lakh L/ha during both the years (Table 4). Similar results for enhanced growth and yield attributes of wheat and maize due to the application of spent wash were also reported by Sukanya and Meli (2004) and Suganya and Rajannan (2009), respectively.

Seed and straw yield of soybean

The data pertaining to seed and straw yield of soybean showed a significant improvement due to the

Table 2. Composition of spent wash used as an amendment

pH	EC (dSm^{-1})	Ca	Mg	Na	K	N	S	BOD	COD
		mgL^{-1}							
4.98	9.42	1522	880	380	8675	990	1150	4110	20660

Table 3. Composition of vermi-compost and FYM used as an amendment

Organic sources	pH (1:4)	EC (dSm^{-1})	Ca	Mg	K	S
			(%)			
Vermicompost	8.5	3.8	0.78	0.38	1.10	0.55
FYM	8.1	1.8	0.45	0.15	0.63	0.20

Table 4. Growth and yield attributes of soybean as affected by different amendments

Treatments applied during reclamation	No. of pods/plant			No. of seeds/pod			Test weight(g)		
	2010	2011	Mean	2010	2011	Mean	2010	2011	Mean
T_1	13.87	14.80	14.34	2.03	1.93	1.98	8.41	8.58	8.50
T_2	16.30	17.03	16.67	2.09	2.00	2.05	8.62	8.66	8.64
T_3	18.67	19.00	18.84	2.13	2.08	2.11	8.70	8.78	8.74
T_4	22.40	24.07	23.24	2.34	2.23	2.29	9.21	9.37	9.29
T_5	23.67	24.60	24.14	2.36	2.23	2.30	9.37	9.39	9.38
T_6	23.80	25.00	24.40	2.37	2.26	2.32	9.42	9.40	9.41
T_7	24.93	26.37	25.65	2.44	2.37	2.41	9.57	9.63	9.60
T_8	27.87	28.33	28.10	2.74	2.63	2.69	10.79	10.85	10.82
T_9	28.60	30.00	29.30	2.77	2.70	2.74	11.11	11.03	11.07
CD (5%)	2.68	1.93	-	0.29	0.11	-	0.36	0.23	-

addition of amendments during both the years. Maximum seed and straw yield of soybean was obtained with the spent wash application of 10.0 lakh L ha^{-1} though it was at with that of 5.0 lakh L ha^{-1} spent wash application. Addition of 5.0 lakh L ha^{-1} spent wash significantly increased the seed and straw yield of soybean as compared to control and other levels of amendments during both the years. Perusal of the data presented in table 5 showed that the seed yield of soybean significantly increased with spent wash application up to 5 lakh L/ha though the highest seed yield (2.48 t/ha) was produced with spent wash application of 10 lakh L/ha. The averaged data over two years showed that application of spent wash applied @ 2.5, 5.0 and 10 lakh L/ha increased the seed yield of soybean by 129.8, 164.4 and 185.0 per cent respectively as compared to control. Application of gypsum @ 75% GR+FYM @ 5t/ha and gypsum @ 75% GR + vermicompost @ 5t/ha also results in significantly lower seed yield (42.7 and 44.1%) and (32.1 and 32.4%) as compared to spent wash application @5 lakh L/ha during both the years. Data also revealed that the straw yield of soybean significantly increased with spent wash application up to 5 lakh L/ha though the highest straw yield (3.04 t/ha) was produced with spent wash application of 10 lakh L/ha. The averaged data over two years showed that application of spent wash applied @ 2.5, 5.0 and 10 lakh L/ha increased the straw yield of soybean by 115.1, 170.5 and 186.8 per cent respectively as compared to control.

Application of gypsum @ 75%GR+FYM @ 5t/ha and gypsum @ 75%GR+vermicompost @ 5t/ha also results in significantly lower straw yield (47.3 and 46.3%) and (38.4 and 38.9%) as compared to spent wash application @5 lakh L/ha during both the years. The beneficial effect of spent wash application on yield of wheat, rice and maize have been reported by Pathak *et al.* (1999), Bhaskar *et al.* (2003) and Sukanya & Meli (2004).

Nutrient concentration in seed and straw

Results emanating from the study showed that addition of 5.0 lakh L/ha spent wash significantly enhanced N, P, K, Ca and Mg content in soybean seeds as compared to control during both the years (Table 6). Maximum content of N, P, K, Ca and Mg in soybean seed was observed with 10.0 lakh L ha^{-1} spent wash

Table 5. Seed and straw yield of soybean as affected by different amendments

Treatments appliedduring reclamation	Seed yield(t/ha)			Straw yield(t/ha)		
	2010	2011	Mean	2010	2011	Mean
T_1	0.81	0.93	0.87	1.01	1.10	1.06
T_2	0.89	1.02	0.96	1.18	1.28	1.23
T_3	1.00	1.14	1.07	1.22	1.33	1.28
T_4	1.43	1.63	1.53	1.74	1.96	1.85
T_5	1.50	1.70	1.60	1.86	2.05	1.96
T_6	1.62	1.85	1.74	1.98	2.16	2.07
T_7	1.86	2.13	2.00	2.10	2.45	2.28
T_8	2.14	2.45	2.30	2.74	3.00	2.87
T_9	2.30	2.65	2.48	2.90	3.17	3.04
CD (5%)	0.24	0.27	-	0.27	0.28	-

Table 6. Nutrient content (%) in soybean seeds under different amendments

Treatments	N		P		K		Na		Ca		Mg	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
T_1	6.21	6.15	0.47	0.45	1.41	1.35	0.32	0.31	0.31	0.31	0.17	0.15
T_2	6.25	6.22	0.48	0.46	1.42	1.37	0.29	0.27	0.34	0.36	0.19	0.17
T_3	6.31	6.23	0.49	0.47	1.44	1.40	0.27	0.25	0.36	0.38	0.20	0.18
T_4	6.35	6.33	0.55	0.53	1.46	1.43	0.25	0.22	0.47	0.49	0.25	0.24
T_5	6.35	6.32	0.57	0.55	1.48	1.44	0.25	0.22	0.52	0.53	0.28	0.26
T_6	6.38	6.35	0.60	0.58	1.50	1.46	0.22	0.20	0.56	0.56	0.30	0.28
T_7	6.41	6.35	0.64	0.63	1.62	1.56	0.18	0.19	0.64	0.61	0.36	0.33
T_8	6.47	6.41	0.66	0.64	1.66	1.61	0.16	0.15	0.67	0.66	0.38	0.36
T_9	6.49	6.42	0.70	0.68	1.67	1.63	0.15	0.13	0.69	0.68	0.39	0.37
CD (5%)	0.08	0.14	0.05	0.06	0.03	0.06	0.03	0.04	0.03	0.03	0.02	0.03

Table 7. Nutrient content (%) in soybean straw under different amendments

Treatments	N		P		K		Na		Ca		Mg	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
T_1	1.42	1.40	0.25	0.23	1.18	1.17	0.58	0.53	0.27	0.28	0.14	0.12
T_2	1.43	1.41	0.26	0.24	1.19	1.21	0.52	0.47	0.29	0.30	0.15	0.13
T_3	1.44	1.40	0.27	0.25	1.21	1.23	0.50	0.44	0.30	0.32	0.16	0.14
T_4	1.45	1.43	0.29	0.26	1.23	1.24	0.46	0.39	0.40	0.41	0.21	0.19
T_5	1.46	1.44	0.30	0.29	1.26	1.28	0.46	0.37	0.44	0.43	0.22	0.20
T_6	1.47	1.46	0.32	0.31	1.28	1.30	0.39	0.36	0.48	0.45	0.24	0.21
T_7	1.48	1.47	0.34	0.33	1.38	1.36	0.33	0.32	0.54	0.50	0.30	0.27
T_8	1.49	1.48	0.36	0.34	1.41	1.39	0.30	0.25	0.57	0.54	0.31	0.28
T_9	1.49	1.49	0.39	0.36	1.42	1.41	0.27	0.23	0.58	0.56	0.32	0.29
CD (5%)	0.02	0.04	0.03	0.03	0.03	0.05	0.04	0.05	0.02	0.04	0.02	0.03

application however, it was at par with 5.0 lakh L ha^{-1} during both the years. The increase in N, P, K, Ca and Mg content of soybean seed at 5.0 lakh L ha^{-1} spent wash application was 4.1, 40.4, 17.7, 116.1 and 123.5 per cent, respectively over control in 2010 and 4.2, 42.2, 19.2,112.9 and 140.0 per cent, respectively over control in 2011. Application of amendments also increased the N, P, K, Ca and Mg content of soybean straw as compared to control during both the years.

Maximum content of N, P, K, Ca and Mg of soybean straw was recorded at 10.0 lakh L ha^{-1} spent wash but it was at par with 5.0 lakh L ha^{-1} in both the years (Table 7). Appreciable increase in N, P, K, Ca and Mg content of straw at 5.0 lakh L ha^{-1} spent wash was 4.9, 44.0, 19.5, 111.1and 121.4 per cent, respectively over control in 2010 and was 5.7, 47.8, 18.9, 92.8 and 100.0 per cent, respectively over control in 2011.

Increase in nutrient content in seed and straw of soybean might be due to the ameliorating effect of spent wash and it also contained higher amount of these nutrients. These present findings are in agreement with those reported by Ramana *et al*. (2002) for P and K in ground nut and Das *et al.* (2010) for N, K, Ca and Mg in rice crop. A sharp reduction in Na content of soybean seed and straw was noticed with the application of amendments (Table 6, 7) during both the years. Maximum decrease in Na content of seed and straw was obtained under 10.0 lakh L ha^{-1} spent wash application which differ non-significantly with the spent wash application 5.0 lakh L ha^{-1}.

Conclusions

Results of present study showed that when different amendments are applied for reclamation of sodic Vertisols, the application of spent wash @ 5 lakh L ha^{-1} produced significantly higher seed yield of soybean grown after three year reclamation process under which the amendments were applied to rice-wheat cropping system. Therefore, it can be concluded that spent wash could be applied successfully as an alternate amendment for reclamation of sodic Vertisols in place of limited available resource of gypsum.

References

Bhaskar, M., Kayalvizi, C., and Subhash Chandra Bose, M. 2003. Eco-friendly utilization of distillery effluent in Agriculture- A review. *Agricultural Review* **24:** 16-30.

Chapman, H.D. and Prett, P.E. 1961. Methods of Analysis of Soils, Plants and Waters. Univ. of California, Wisconsin USA.

Das, M. Chakraborty, H., Singandhupe, R.B., Muduli, S.D. and Kumar, A. 2010. Utilization of distillery waste water for improving production in undr productive Paddy grown area in India. *J. Scientific and Industrial Research* **69:** 560-563.

Mandal,A.K.,Sharma,R.C.,Singh,Gurubachan and Dagar, J.C. 2010. Computerized database on Salt Affected Soils in India. *Tech. Bull*. CSSRI, Karnal 2/2010. Central Soil Salinity Research Institute, Karnal. 28p.

Pathak, H. Joshi, H.C. Chaudhary, A. Chaudhary, R., Kalra, N. and Dwivedi, M.K. 1999. Soil amendments with distillery effluent for Wheat and Rice cultivation. *Water, Air and Soil Pollution* **113:** 133-140.

Ramana, S. Biswas, A.K. Singh, A.B. and Yadav R.B.R. 2002. Relative efficacy of different distillery effluents on growth, nitrogen fixation and yield of groundnut. *Bioresource Technology* **81:** 117-121.

Richards, L.A. (Ed.) 1954. Diagnosis and Improvement of Saline and Alkali Soils. Hand Book No. 60 USDA, Washington D.C.

Sharma, R.C. 1996. Comments on The Report on " Status of Land Degradation in India". Dept. Soil and Water conservation, Govt. of India, New Delhi.

Suganya, K. and Rajannan, G. 2009. Effect of one time post sown and pre-sown application of distillery spentwash on the growth and yield of maize crop. *Bot. Res. Intl*. **2:** 288-294.

Sukanya, T.S. and Meli, S.S. 2004. Response of Wheat to graded dilution of liquid distillery effluent on plant nutrient contents, nutrient up-take, crop yield and residual soil fertility. *Karnataka J Agric. Sci*. **17:** 417-420.

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Euphorbia antisyphilitica : A potential petro-crop for degraded calcareous soils and saline water irrigation in dry regions of India

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ABSTRACT

Euphorbia antisyphilitica commonly known as Candelilla Wax plant is a succulent laticiferous potential hydrocarbon yielding petro-crop. It yields 8-10 % biomass utilized as bio-fuel. It can be grown successfully on degraded sandy and calcareous soils in arid and semi-arid regions. The crop, when irrigated with saline water, produced ~ 23 t ha^{-1} dry biomass in 2 years. Results of present investigation proved it to be a low nutrient demand crop as it required only 16 and 40 kg ha^{-1} of phosphorus and nitrogen, respectively for optimum biomass production. It is also low-water requiring and produced 17.5 and 15.25 t ha^{-1} dry biomass with saline water (12 dS m^{-1}) irrigation at Diw: CPE ratio of 0.1 and 0.2, respectively as compared to 10.9 t ha^{-1} under rain-fed condition. For large scale cultivation it can be grown successfully on marginal calcareous and sandy soils of dry regions and one or two life saving irrigations with saline water will give optimum biomass.

Keywords: Bio-fuel, calcareous soil, *Euphorbia antisyphilitica*, Candelilla, petro-crop

Introduction

Comparing the forecasted increase in energy demand and available crude mineral oil resources, it is evident that the future energy requirement cannot be met by fossil fuels alone. Without suitable alternatives to crude mineral oil, the global economy will suffer a drastic collapse because of exploding oil prices as a consequence of continuously increasing energy demand expected to arise for maintaining the sustainable future growth of society and economy (Sake *et al.*, 2013). To meet the challenge of the increasing demand of energy, alternative sources of energy and new technology for exploiting the available biomass sources, the biologists need special focus. The bio-fuels have been categorized based on their method and principle application namely as first, second, third and fourth generation bio-fuels, *etc.* (Sorrel *et al*., 2009). The first generation bio-fuels are prepared from biomass consisting of either sugar from sugarcane, sugar beet; starch from corn/maize, cassava; second generation bio-fuels are vegetable oils from soybean, rapeseed; third generation include non-edible oils from *Jatropha, Pongamia*, Castor, animal fats, etc.; and the fourth generation bio-fuels are derived from ligno-cellulosic biomass such as stalks of wheat, corn, switch grass and wood like poplar using advanced technological process. Food and bio-fuels are reliant on same resources for productions *i.e.* land, water and energy. Most of the arable fertile lands cannot be diverted from food producing crops to bio-fuel crops; hence the degraded marginal lands need to be brought under cultivation of bio-fuel crops. Therefore, selecting suitable species from non-food sources, having ability to grow on marginal and degraded lands and sustain production with low quality and quantity water usage may help in mitigating this conflict to a greater extent (Escamilla-Trevino *et al.*, 2010).

The importance of hydrocarbon producing plants, also popularly known as "petro-crops" can provide alternative energy source have come into focus in recent years (Kumar, 1994, 1995; Johari and Kumar, 2013; Sake *et al.*, 2013). Many of these (e.g. *Euphorbia* species-*lathyris, tirucalli, antisyphilitica, caducifolia, neriifolia*; *Pedilanthus tithymalidas*, *Calotropis procera* and *C. gigantea*) can be grown successfully on waste lands or marginal lands of semi-arid and arid regions with no water requirement or meagre requirement of low quality water and without much agricultural inputs and management (Sake *et al.*, 2013). *Euphorbia antisyphilitica* Zucc., commonly known as Candelilla wax plant, is a species of spurge native to the Trans-Pecos of Texas and Southern New Mexico in the United States as well as Chihuahua, Coahuila, Hidalgo and Queretaro in Mexico (http://en.wikipedia.org/wiki/Euphorbia_antisyphilitica). The white sap of this plant was historically used in Mexico to treat sexually-transmitted diseases. Commercial harvesting of Candelilla wax began at the start of 20th century, with demand greatly increasing during World War I & II. The succulent plant has milky latex in the vacuoles of specialized secretory cells called laticifers. It possesses unique features with regard to chemical composition that makes it possible bio-resource for production of bio-fuel. Recently, the residue has been found as a new source of ellagic acid (Ascacio-Valdes *et al.*, 2010) adding the extra value to the plant.

Though seeing the importance, people advocate strongly for cultivation of bio-fuel crops (Bhatia *et al.*, 1993; Kumar, 2001) but the interest in the area of production of bio-fuels hydrocarbon yielding plants has declined, because of the fact that growing these crops merely to obtain bio-fuel by tapping, extraction and by hydro-cracking of bio-crude cannot be cost-effective (Sake *et al.*, 2013). However, if the spent residue acquired after the extraction of bio-crude from petro-crops could be effectively utilized to get value added fuels and chemicals then petro-farming could become a viable alternative for production of bio-fuels from petro-crops. As stated above, many species of *Euphorbia* do not compete with conventional food crops and can be cultivated successfully on degraded marginal lands with very little or no requirement of water as is the case in arid and semi-arid regions. Most of the regions do not have sufficient good quality irrigation water and posses only saline groundwater aquifers. Therefore, in present investigation, both in field and pot-house experiments have been conducted to work out the possibility of utilizing saline water for cultivation of *Euphorbia antisyphilitica*, one of the most potential petro-crops (Kumar, 1990, 1994, 1995, 2001; Johari and Kumar, 2013).

Material and methods

Site climate and soil description

The field study was carried out at Bir Forest, Hisar ($29^0$10'N and $75^0$44'E with altitude of 215.2 m above MSL) in Haryana state in north-western part of India. The climate of the experimental site is semi-arid monsoon type with an annual rainfall of 499 ± 165 mm and open pan evaporation 1888 ± 243 mm (average of 21 years from 1991-2011). Most of the rain (70-80 %) occurs during July to September. The mean daily maximum and minimum temperatures recorded during same period were 31.3 ± 0.8 and 16.1± 0.8 ^{0}C, respectively. The annual rainfall during two years of study period was 340 and 493 mm. The soil characteristics of the experimental site are given in table 1. The soil is sandy loam highly calcareous (Typic Haplustalf) with mean $CaCO_3$ in profile ranged from 6.2 to 9.4 %. The water used for irrigation had electrical conductivity (EC) of 12 dS m^{-1} and SAR ~20. The following experiments were conducted in field:

Experimental details

Experiment 1: Effect of nitrogen and phosphorus on biomass production

This field experiment consisted of 12 treatment combinations comprising of 4 levels of nitrogen (0, 40, 60 and 80 kg ha^{-1}) and 3 levels of phosphorus (0, 16 and 32 kg P_2O_5 ha^{-1}) arranged in complete block factorial RBD design with 4 replications. Full dose of P and half dose of nitrogen were applied basal and remaining half dose of nitrogen was applied after 12 months of crop growth. The rooted slips of *Euphorbia* were planted at 50 x 50 cm plant to plant and row to row distance in 4m x 4m size plots, thus accommodating 64 plants in each treatment plot.

Experiment 2: Effect of saline water irrigation schedules on biomass production

This experiment consisted of 5 irrigation schedules based upon ratio of irrigation water applied (7cm) and cumulative pan evaporation, i.e. Diw: CPE of 0.1, 0.2, 0.4, 0.6 and 0.8, respectively. One treatment was also kept without supplemental irrigation *i.e.* rain-fed. The experiment was laid out in randomised complete block design with four replications.

Two pot-house experiments were carried out under control conditions. In one experiment 16 pots (40 cm height and 40 cm diameter) were filled with 20 kg of each of 5 soil mixtures. Five soil mixtures were prepared using air dried calcareous soil brought from the experimental field site and mixed with sand in soil: sand ratio of 0:4, 1:3, 2:2, 3:1 and 4:0. One rooted *Euphorbia* sapling was planted in each pot and such 20 pots were irrigated with water of each of the four salinity levels i.e. 0.4 (tap water), 4, 8 and 16 dS m^{-1}. Initially 8 litre designated salinity water was applied to bring the soil moisture to field capacity followed by two litre applied at weekly interval. The

Table 1. Initial physico-chemical properties of the soil

Soil depth (cm)	Clay (%)	Silt (%)	Sand (%)	pH (1:2)	ECe (dS m^{-1})	$CaCO_3$ (%)
0-15	18.2	19.4	62.4	8.1	2.0	6.2
15-30	18.0	22.2	59.8	8.3	1.8	8.2
30-60	17.6	21.8	60.6	8.0	2.1	9.4
60-90	17.2	21.2	61.6	7.9	2.6	8.6
90-120	17.4	22.4	60.2	7.8	2.9	8.1

treatment pots were arranged in complete block randomised design (RBD) with four replications of each treatment combination.

In second pot experiment, plants were raised in pots filled with same calcareous soil after mixing different doses of N, P and K fertilizers. The treatments consisted of 3 nitrogen (0, 20, 40, mg kg^{-1} soil), 3 phosphorus levels (0, 7.5 and 15 mg P_2O_5 kg^{-1} soil) and 3 potassium (0, 20 and 40 mg kg^{-1} soil) levels. The total 27 combinations each with 4 replications were arranged in RBD design. The crop in pots was irrigated with tap water as per the schedule followed in earlier pot experiment. Both the experiments were carried out for 9 months (February – October).

Sampling and analytical procedures

After preparing the field for planting, the soil samples were collected from different places in the field to make the representative sample. These were air dried, ground and passed through a 2 mm sieve. Extract of saturated soil paste prepared in distilled water and obtained using the vacuum pump was analyzed for electrical conductivity (ECe) as described by Richards (1954) and pHs using digital pH meter. The mechanical analysis of initial soil samples was done as per the International Pipette method (Piper, 1966). Soil samples were also collected after 2 years of experimentation from each of the treatment plots and analyzed for ECe and pHs to ascertain the changes with imposition of respective treatments. The samples of irrigation water were analyzed for EC, pH and composition of different cations and anions described by Richards (1954). The Na^+ and K^+ were determined with the help of flame photometer while the Ca^{2+} + Mg^{2+} as per standard procedure described in Jackson (1967). As most of the saline nature ground waters contain chlorides and sulphates of sodium, magnesium and calcium, therefore, the saline water used in pots was prepared dissolving salts of NaCl, $MgSO_4$ and $CaCl_2$ in distilled/ tap water to make the water of desired salinity ranging from 4 to 16 dS m^{-1}. Care was taken that sodium adsorption ratio (SAR) was maintained < 10 while preparing the water of desired salinity levels. The treatment with tap water (EC 0.4 dS m^{-1}) was kept as control. In both pot experiments, the plants were harvested in first week of November at 9 months of growth and fresh biomass was recorded after taking the height of the plants. Chlorophyll content in plants subjected to different treatments in second experiment was measured as per Arnon (1949).

Statistical analysis

The significance of differences among means of different treatments and their interactions in respective field and pot experiments were judged using least significant difference (LSD) computed at 5% level of Tukey's adjustment after ANOVA test in CRD and factorial RBD designs using MStat-C program.

Results and discussion

Euphorbia antisyphilitica, a succulent plant found growing naturally on marginal soils in arid and semi-arid conditions in Texas and southern New Mexico, shows natural adaptability to prevailing water deficit and resistance to plant and insect attacks (Sake *et al.*, 2013). Cultivation of this plant offers more productive utilization for bio-fuel production and carbon sequestration of otherwise lying fallow marginal and degraded lands (Kalita and Saikia, 2003). To find out the water requirement, one field experiment was conducted to optimize the irrigation schedules of utilizing available saline (of ECiw 12 dS m^{-1}) groundwater regimes ranging from rain-fed (control) to irrigations at Diw:CPE ratio 0.1, 0.2, 0.4, 0.6 and 0.8. Maximum biomass production was recorded when crop received irrigations at Diw: CPE ratio 0.2 plus rains followed by irrigations at Diw: CPE ratio of 0.4. The increase in dry biomass with irrigations scheduled at Diw: CPE ratio of 0.1 and 0.2 was 60 and 40%, respectively as compared to rain-fed. But with further wetter regime irrigation schedules there was drastic reduction in biomass production of *Euphorbia* (Table 2), showing that annually only 4-5 irrigations are sufficient for this crop to produce the optimum biomass. There was also increase in soil salinity build up with application of more number of irrigations (Figure 1) suggesting that though this is extremely low water requiring crop but only moderately tolerant to salts. Four or five life saving irrigations of even saline water increases the biomass to the considerable amount. It is unlike other low water requiring crops such as psyllium (*Plantago ovata*) which could provide higher yield with increase in number of irrigations in 4 months crop period (Tomar *et al.*, 2010) and gradual increase in biomass recorded with increased frequency of saline irrigation in lemon grass (Dagar *et al.*, 2013). For increasing productivity of *E. antisyphilitica* Johari and Kumar (1992) studied the impact of fertilizers in pots and found that supplementation of nutrients

Table 2. Effect of depth of irrigation (Diw/CPE ratio) of saline water (ECe 12 dS m^{-1}) on biomass production of *Euphorbia antisyphilitica*

Depth of Irrigation (Diw/CPE)	Fresh biomass (t ha^{-1})	Dry biomass (t ha^{-1})
Rainfed	68.13	10.92
0.8	30.25	4.85
0.6	40.63	6.55
0.4	55.75	8.96
0.2	104.52	18.29
0.1	94.38	17.40
LSD (p = 0.05)	11.82	2.01

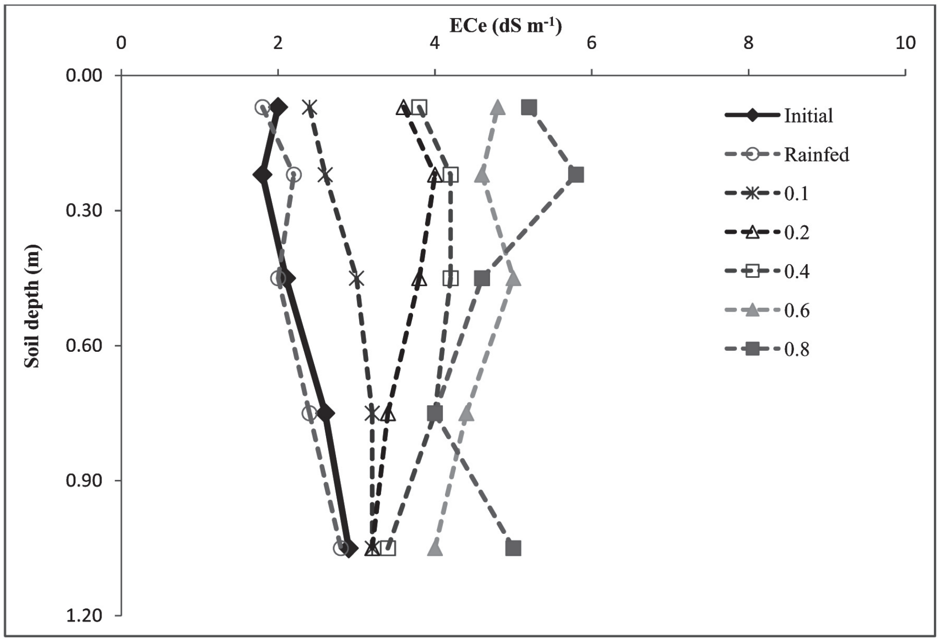

Fig. 1. Development of salinity in soil profile when *Euphorbia antisyphilitica* was irrigated with different Diw: CPE ratio

promoted the growth and productivity including the bio-crude contents which are 8-10 % of dry biomass. In present study, there was gradual increase in biomass with increase in phosphorus and nitrogen doses (Table 3) but there was no significant difference in biomass when 32 kg ha^{-1} phosphorus was applied showing that only 16 kg ha^{-1} phosphorus was sufficient. Similarly, no significant difference in biomass was recorded at 60 and 80 kg ha^{-1} nitrogen implying that nitrogen at the rate of 60 kg ha^{-1} is sufficient. Similar trend in biomass production was true when the study was carried out in pots (Table 4). But in pot-studies the impact of potassium was clearly visible. Earlier, Kaicker *et al*. (1975) in poppy and Johari and Kumar (1992) in *Euphorbia* reported increased biomass and latex yield with application of N whereas with application of K, could produce higher bio-crude than to N and P application. Chlorophyll content and biomass production increased significantly when N, P, & K fertilizers were applied (Table 5). Similar observations were recorded on cholorophyll content in *Euphorbia* by Johari and Kumar (1992).

In most of the arid and semi-arid areas the degraded soils are calcareous in nature. *Euphorbia antisyphilitica* has been found to be quite successful particularly in sandy soils. In one pot study Johari and Kumar (2013) observed highest biomass in red soils which are predominant in arid zone of peninsular India. This was followed when red soil was mixed with sand and gravel and also when sand alone was taken. In present pot study using water of different salinity the maximum biomass was obtained when sand and calcareous soil were mixed in 3:1 ratio followed by sand : calcareous 2:2 ratio and 1: 3 ratio when irrigated with water of ECiw 4 dS m^{-1}. The crop

Table 3. Effect of nitrogen and phosphorus on above ground biomass production (t ha^{-1}) of *Euphorbia antisyphilitica* after two years of growth

Nitrogen	Phosphorus					
	Fresh biomass			Dry biomass		
	P_0	P_{16}	P_{32}	P_0	P_{16}	P_{32}
N_0	95.2	102.3	116.5	16.2	17.4	19.8
N_{40}	118.2	126.7	128.0	20.2	21.8	22.3
N_{60}	123.2	128.4	129.5	21.2	22.2	22.4
N_{80}	124.4	132.5	133.5	21.3	22.8	23.3
Mean	115.3	122.5	122.5	19.7	21.1	22.0

LSD (p = 0.05)	Fresh	Dry
N	2.4	0.4
P	2.1	0.3
N x P	4.2	0.7

Table 4. Effect of N, P and K fertilizers on plant height and fresh biomass of *Euphorbia antisyphilitica*

Phosphorus	Potassium	Nitrogen								
		N_0			N_{20}			N_{40}		
		Height (cm)	Biomass (kg/plant) AG	Biomass (kg/plant) BG	Height (cm)	Biomass (kg/plant) AG	Biomass (kg/plant) BG	Height (cm)	Biomass (kg/plant) AG	Biomass (kg/plant) BG
P_0	K_0	63.8	2.41	0.62	75.0	4.28	1.26	78.5	4.68	1.46
	K_{20}	64.5	3.07	0.74	84.0	4.36	1.32	86.5	4.80	1.58
	K_{40}	72.0	3.41	0.92	90.2	4.40	1.41	92.4	4.92	1.62
P_{16}	K_0	69.8	3.26	0.86	90.5	4.38	1.40	93.0	4.72	1.48
	K_{20}	76.8	3.36	0.90	91.2	4.42	1.45	93.8	4.97	1.65
	K_{40}	79.8	3.52	0.93	92.0	4.51	1.52	94.2	5.06	1.70
P_{32}	K_0	82.8	3.45	0.95	90.0	4.45	1.48	95.4	4.86	1.62
	K_{20}	83.0	3.81	1.08	91.5	4.56	1.50	96.0	5.15	1.73
	K_{40}	83.5	3.95	1.23	93.2	5.05	1.53	97.8	5.46	1.82

LSD(p = 0.05)	Height	Biomass
N	0.84	0.08
P	0.67	0.04
K	0.37	0.05
N x P	1.16	0.06
N x K	NS	0.08
P x K	0.65	0.08
N x P x K	1.12	0.14

AG-aboveground biomass, BG-belowground biomass
Subscript values represent amount applied as kg ha^{-1} of nitrogen (N), phosphorus (P) and potassium (K)

Table 5. Effect of N, P and K fertilizers on chlorophyll contents of *Euphorbia antisyphilitica*

Phosphorus	Potassium	Nitrogen								
		N_0			N_{20}			N_{40}		
		a	b	Total	a	b	Total	a	b	Total
		Chlorophyll (mg g^{-1}) fresh weight								
P_0	K_0	0.410	0.215	0.625	0.558	0.264	0.822	0.620	0.276	0.896
	K_{20}	0.556	0.294	0.850	0.610	0.303	0.913	0.660	0.282	0.942
	K_{40}	0.604	0.346	0.950	0.632	0.312	0.944	0.675	0.294	0.969
P_{20}	K_0	0.486	0.235	0.721	0.578	0.272	0.850	0.640	0.280	0.920
	K_{20}	0.525	0.305	0.830	0.634	0.345	0.979	0.784	0.362	1.146
	K_{40}	0.587	0.365	0.952	0.625	0.358	0.983	0.664	0.328	0.992
P_{40}	K_0	0.450	0.265	0.715	0.542	0.276	0.818	0.670	0.294	0.964
	K_{20}	0.480	0.225	0.705	0.584	0.282	0.866	0.680	0.360	1.040
	K_{40}	0.515	0.245	0.760	0.610	0.312	0.922	0.690	0.315	1.005

LSD (p=0.05)	a	b	Total
N	0.014	0.001	0.012
P	0.007	0.001	0.007
K	0.005	0.001	0.005
N x P	0.013	0.002	0.0013
N x K	0.009	0.002	0.008
P x K	0.009	0.002	0.008
N x P x K	0.016	0.003	0.014

biomass production with ECiw 4 dS m^{-1} water irrigation was even higher than when irrigated with tap water (ECiw ~ 0.4 dS m^{-1}) showing that the plant also requires some salt for its optimum growth. The pattern remained the same in different sand: soil relationships when irrigated with saline water but the biomass decreased when salinity of irrigation water increased (Table 6).

Table 6. Performance (biomass kg/plant) of *Euphorbia antisyphilitica* when grown in different proportion of sand: calcareous soil and irrigated with water of different salinity (After 9 months of growth March-November)

Sand: soil ratio	ECiw (dS m^{-1}) of irrigation water				
	Tap water	4	8	12	16
4:0	1.66	1.72	1.48	1.42	1.28
3:1	2.22	2.32	1.83	1.65	1.50
2:2	1.87	2.00	1.76	1.58	1.37
1:3	1.77	1.96	1.64	1.44	1.31
0:4	1.74	1.82	1.55	1.38	1.28

LSD (p = 0.05)	
Between sand: soil mixture (A)	0.18
Between ECiw of irrigation water (B)	1.17
Interaction (A) x (B)	NS

References

Arnon, D.I. 1949. Copper enzymes in isolated chloroplasts Polyphenoloxidase in *Beta vulgaris*. *Plant Physiology* **24**: 1-15.

Ascacio-Valdes, J.A., Aguilera-Carbo, A., Martinez-Hernandez, J.L., Rodriguez-Herrera, R. and Aguilar, C.N. 2010. *Euphorbia antisyphilitica* residue**s** as a new source of ellagic acid. *Chemical Papers* **64(4):** 528-532.

Bhatia, V.K., Padmaje, K.V., Kaimra, S., Singh, J. and Badani, R.P. 1993. Upgrading of biomass constituents to liquid fuels. *Fuel* **72**: 101-104.

Dagar, J.C., Tomar, O.S., Minhas, P.S. and Kumar Mukesh. 2013. Lemongrass (*Cymbopogon flexuosus*) productivity as affected by salinity of irrigation water, planting methods and fertilizer doses on degraded calcareous soil in a semi-arid region of northwest India. *Indian Journal of Agricultural Sciences* **83(7):** 734-738.

Escamilla-Trevino, L.L., Shen, H., Uppalapati, S.R., Ray, T., Tang, Y. and Hernadez, T. 2010. Switchgrass (*Panicum virgatum*) possesses a divergent family of cinnamoyl CoA reductases with distinct biochemical properties. *New Phytologist* **185**: 143-155.

Jackson, M.L. 1967. *Soil Chemical Analysis*. Asia Publishing House, New Delhi.

Johari, S. and Kumar, A. 1992. Effect of N, P and K on growth and biocrude yield of *Euphorbia antisyphilitica*. *Annals of Arid Zone* **31(4):** 313-314.

Johari, S. and Kumar, A. 2013. Improving growth and productivity of *Euphorbia antisyphilitica*: A biofuel plant for semi-arid regions. *International Journal of Life Sci. & Pharma Res.* **3(4):** 20-24.

Kaicker, V.S, Singh, B., Turkhede, D.B., Singh, H.P., Chaudhary, B. and Betrax, A.R. 1975. Varietal yield of opium at different fertilizer levels. National Symposium on *Recent Advances in the Development, Production and Utilization of Medicinal & Aromatic Plants*. CIMPU, Lucknow, 24-26 Feb., 1975.

Kalita, D. and Saikia, C.N. 2003. Chemical constituents and energy content of some latex bearing plants. *Bioresour. Technol.* **92(3):** 219-227.

Kumar, A. 1990. Prospects of raising latex bearing plants in semi-arid and arid regions of Rajasthan. In: Grassi, G., Gosse, G. and Santos, G. dos (eds). *Biomass for Energy and Industry* Vol. I. Elsevier Applied Sci. London, pp 1.100-1.107.

Kumar, A. 1994. Laticifers as potential bioremedients for wasteland restoration. *J. Environment & Pollution* **1:** 101-104.

Kumar, A. 1995. Cultivation of hydrocarbon yielding plants in Rajasthan as an alternative energy source. *J. Environment & Pollution* **2**: 67-70.

Kumar, A. 2001. Bioengineering of crops for biofuels and bioenergy. In: Beuder, L. and Kumar, A. (eds). *From Soil to Cell: A Broad Approach to Plant Life*. Giessen Electron Library, pp 1-16.

Piper, C.S. 1966. *Soil and Plant Analysis*. Waite Agriculture Research Institute, Univ. of Adelaide, Australia.

Rechards, L.A. 1954. *Diagnosis and Improvement of Saline and Alkali Soils*. USDA, Washington DC.

Sake, P.K. Bugude, R., Reddy, V. and Shavalli Khan, P.S. 2013. Production of bioethanol from spent residues of latex yielding plants *Euphorbia antisyphilitica* L. and *Euphorbia caducifolia* Haines. *International. J. Recent Sci. Research* **4(6):** 936-942.

Sorrell, S., Speciess, J., Bentley, R., Brandt, A. and Miller, R. 2009. An assessment of the evidence for a near-term peak in global oil production. Report, UK Energy Research Centre, London.

Tomar, O.S., Dagar, J.C. and Minhas, P.S. 2010. Evaluation of sowing method, irrigation schedules, chemical fertilization doses and varieties of *Plantago ovata* Forsk to rehabilitate degraded calcareous lands irrigated with saline water in dry regions of northwestern India. *Arid Land Research & Management* **24**: 133-151.

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Soil aggregates as indicator of soil health in waterlogged sodic soil

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ABSTRACT

The aggregates are considered to be indicators of soil health. Soil rich in organic carbon and physical properties have higher water stable aggregates. In present investigation the distribution of water stable aggregates and their indices were compared in waterlogged sodic soil with non-waterlogged soil profiles. Average maximum total water stable aggregates (45.16%) were recorded in 0-15 cm soil depth and they decreased with increased soil depth. In 0-15 cm soil depth, macro aggregates increased from 9.9% in soil with pH 8.5 to 20.3% in soil with pH 9.5 in waterlogged condition and the same decreased to 2.84% on the same soil in non waterlogged condition. However, in soil with pH 8.5 in waterlogged condition, macro aggregates increased to 9.9 and 11.4% in 0-15 cm and 15-30 cm soil depths, respectively. In soil with pH 9.5, however, in waterlogged condition macro aggregates decreased with increasing soil depth.

Key words: soil aggregates, sodic soil, waterlogging, water stable aggregates

Introduction

Soil aggregate is a group of primary soil particles which cohesion within by soil physical, chemical and biological influences. Some of the most important factors influencing the aggregation include surface tension, intermolecular attractive forces between water and solids, precipitated solutes, roots and fungal hyphae and various chemical phenomena. The complex dynamics of aggregation are the result of the interaction of many factors, including the environment, soil management factors, plant influences and soil properties such as mineral composition, texture, soil organic carbon (SOC) concentration, pedogenic processes, microbial activities, exchangeable ions, nutrient reserves, and moisture availability (Kay, 1990). These soil aggregations are the basic index for appraisal of soil physical properties, especially structure, and that are important to sustain soil fertility by reducing soil erosion and mediates air permeability, water infiltration and nutrient cycling (Spohn and Giani, 2011; Zhang *et al.*, 2012). These are the most important agent of retaining soil organic carbon and protect against the decomposition of organic matter (Six *et al.*, 2000). Soil aggregate stability has also been shown to provide a good index of soil erodibility (Kay, 2000; Diaz-Zorita *et al.*, 2002). The soil aggregate stability may be affected by soil texture, organic matter, soil and moisture content (Mostaghimi *et al.*, 1988; Oztas and Fayetorbay, 2003). The abundant water stable aggregates (WSA) in size 0.25-0.1 mm at the upper soil surface layer (0-15 cm) determine the potential for sheet erosion and crust formation (Shouse *et al.*, 1990). For the assessment of physical properties of such soil; and for sustainable crop production and soil health, it is important to examin water stable aggregate (WSA) distribution across the soil profile. Aggregates occur in a variety of manner and size. These are often grouped by size: macro aggregates (>0.25 mm) and micro aggregates (< 0.25 mm) with these groups being further divided by size depending upon soil properties such as binding agents and carbon and nitrogen (N) distribution (Tisdall and Oades, 1982).

To feed ever increasing population more infrastructure such as irrigation facilities, will be required. However, canal irrigation in arid and semi-arid region increased the ground water table over the years followed by waterlogging and secondary soil salinization (SSS). Waterloggong and SSS have affected soil physical properties. Raise in water table is one of major degrading processes of canal command areas in arid and semi-arid regions of world and resultant accumulation of salts in excess for practical and normal production of crops (Ram *et al.*, 2011). These areas mostly exist adjacent to canals especially where drainage facilities are poor, canal levels are higher than ground level and where ground water is of poor quality and is not pumped at rates sufficient to enough to arrest rise in water table due to seepage. Even un-irrigated areas, low lying parts, which act as discharge sites are prone to waterlogging and saline seep problems. Therefore, it is very important to learn how the soil aggregation pattern performed in soil profile under waterlogged conditions. In present investigation an

Table 1. Soil parameters of waterlogged and non-waterlogged micro-plots (mean of 3)

Soil group	Soil depth (cm)	Sand (%)	Silt (%)	Clay (%)	pH		ESP (Initial)	
					Range	Mean	Range	Mean
A	0-15	47.4 ± 0.4	31.3 ± 1.5	21.4 ± 0.7	8.2-8.8	8.6	26.2-34.2	30.2 ± 0.5
	15-30	46.8 ± 0.5	30.7 ± 1.1	22.6 ± 0.5	8.2-8.7	8.6	24.8-35.6	30.2 ± 0.6
	30-45	46.9 ± 0.3	31.5 ± 1.0	22.1 ± 0.8	8.0-8.6	8.4	25.4-34.4	29.9 ± 0.4
	45-60	46.4 ± 1.2	31.2 ± 0.5	22.8 ± 0.9	8.0-8.5	8.4	27.5-35.8	31.7 ± 0.5
	Mean	46.8	31.0	22.2	-	8.5	-	30.5
B	0-15	48.4 ± 0.7	31.0 ± 0.6	22.7 ± 0.5	9.3-9.8	9.7	41.1-61.2	50.7 ± 0.5
	15-30	47.6 ± 0.6	31.1 ± 0.8	21.4± 0.6	9.2-9.7	9.5	42.7-58.2	50.5 ± 0.5
	30-45	47.6 ± 0.8	31.5 ± 0.6	20.9 ± 0.5	9.0-9.4	9.4	37.8-61.0	49.4 ± 0.6
	45-60	46.5 ± 0.8	31.8 ± 0.7	21.8 ± 0.5	9.0-9.3	9.4	40.5-59.3	49.9 ± 0.9
	Mean	47.5	31.3	21.2	-	9.5	-	50.1

attempt have been made to investigate aggregate pattern of waterlogged sodic soil under control conditions.

Material and methods

The present study was carried out at Central Soil Salinity Research Institute, Karnal (latitude 29^{0}43' N, 76^{0}58' E, altitude 245 msl) in Haryana State, India. The climate of the area is subtropical, semiarid, with little or no water surplus megathermic and monsoonal. The actual mean annual rainfall measured at the institute during study period was found to be 800 mm. The maximum rainfall (78%) occurred during July to September. The mean maximum and minimum daily temperatures were 31.3^{0}C and 17.8^{0}C, respectively.

Experimental details

For the assessment of water stable aggregates and their indices two soil conditions were investigated first waterlogged and other non-waterlogged having two pH groups-one pH ranging from 8.2-8.8 (average 8.5) and another from pH 9.3-9.7 (average 9.5); each group having three replications. The initial soil properties are shown in Table 1.

The study was conducted in 12 micro-plots each 6 m x 3 m in size and 90 cm deep constructed by bricks and cement. The soil profile in all the plots was 90 cm deep. Artificially created waterlogging conditions were developed in six micro plots by lining with plastic sheets before filling the soil and installing PVC pipes at bottom of micro-plot connecting with water tank (6m x 0.5m and 0.9m depth) constructed parallel to the micro-plots. The water table was maintained by filling the water tank regularly up to the brim of micro-plot. The water entered to micro-plots by seepage through PVC pipe and came to the surface by capillary action in the soil. The water in reservoir replenished every day that lost through evaporation/ transpiration. Another six micro-plots were maintained as without waterlogging.

After six months of waterlogging intensive soil sampling of micro-plots were done following standard procedure from the soil depth of 0-15, 15-30, 30-45 and 45-60 cm. Soil samples were divided in two parts. First part used for chemical analysis. After grinding, the air dried soil samples were passed through a 2 mm sieve and analyzed for different soil parameters. The mechanical analysis was done by the Pipette method (Piper, 1967). Another part air dried ungrounded samples were passed through 5 mm sieve and were used for estimating aggregate size distribution by wet sieving method (Yoder, 1936) by using a set of sieves having pore diameter 2.0, 1.0, 0.5, 0.25, 0.10 and 0.05 mm for the measurement of total water stable aggregate percentage, macro aggregate percentage, aggregate stability, mean weight diameter and geometry mean diameter. Samples were used for estimating such indices without dispersion and after dispersion with 5% (w/v) sodium hexametaphosphate in 1:3 (soil: solution) ratio by mechanically stirring the suspension for five minutes before the vertical oscillation of the apparatus for 30 minute at the frequency of 50 cycles per minute with taking care that the samples on the top sieve remain immersed throughout the stroke. Before starting the oscillation, soil was left for shaking in water for two minutes. Sieves were then taken out and kept until water was drained out. The water stable aggregates (without dispersion) of different sizes were collected from the respective sieves separately and weighted after oven drying at 50 ^{0}C for 24 h. Water stable macro aggregate and total water stable aggregate: The macro aggregates were determined by adding the aggregates retained over 0.25 – 2.0 mm sieves while the total water stable aggregates referred to adding retained on 0.05 – 2.0 mm sieves using the formula:

$$WSA (\%) = [(\text{weight of soil + sand})*i - (\text{weight of sand})] / \text{weight of soil sample}$$

where 'i' denotes the size of the sieve. The percentage of water stable macro-aggregates and water stable micro-aggregates is the summation of soil aggregates size fractions of >0.25 mm and <0.25 mm, respectively. These two summed up to estimate the total water stable aggregates.

Mean weight diameter (MWD) and geometry mean diameter (GMD) of aggregates were calculated as:

$$MWD\ (mm) = \Sigma^{n}_{i=1} XiWi / \Sigma^{n}_{i=1} Wi$$

$$GMD\ (mm) = \exp [\Sigma^{n}_{i-1} Wi \log Xi / \Sigma^{n}_{i-1} Wi]$$

where n is the number of fractions (0.1-0.25, 0.25-0.50, 0.50-1.0, 1.0-2.0 and >2.0 mm), Xi is the mean weight diameter (mm) of the sieve size class (0.175, 0.375, 0.75, 1.5 and 2.0 mm) and Wi is the weight of soil (g) retained in each sieve.

The aggregate stability (AS) of soils was computed as:

As = (Percent soil particles >0.25 mm – Percent primary particle >0.25 mm)/ (Percent primary particle <0.25 mm)

The aggregate ratio (AR) of soils was computed as:

AR = [Percent of water stable macro-aggregates]/ [Percent of water stable micro-aggregates]

Statistical analysis

Statistical analysis was performed using SPSS programme to determine the statistical significance of soil condition effect. Duncan's Multiple Range Test (DMRT) was used to compare mean through least significant difference. The 5% probability level is regarded as statistically significant.

Results and discussion

In the present investigation the distribution of soil mass among the size classes of water stable aggregates are strongly influenced (significant at p = 0.05) by the waterlogging condition of soil and soil pH in the soil profile range depth from (0-15, 15-30, 30-45 and 45-60 cm soil depth). The total water stable aggregates and its indices such as AR, MWD, GMD and AS are higher in surface layer than in sub-surface layers (Table 2).

The results showed that total water stable aggregates were found higher (45.16%) in 0-15 cm layer to be 10.31%, 3.49% and 3.37% in lower 15-30, 30-45 and 45-60 cm depth, respectively. Das, *et al*. (2014) also reported that the soil aggregates decreased with increasing the soil depth. Although, the higher total water stable aggregates in surface layer could be cause of contained more organic matter which added by crop residues. Shreyasi *et al*. (2014) expressed in a study that soil aggregation increased by improving of organic matter in soil, which can manage through conservational tillage and residue management, in tropical soils. However, the maximum (64.52%) total water stable aggregates were found in non-waterlogged pH 8.5 soil condition in 45 to 60 cm soil depth followed by (60.12%) in 15-30 cm soil depth (Fig. 1). The contained of water stable aggregates in soil improved the nutrient status especially nitrogen and carbon (Qiang *et al*., 2007).

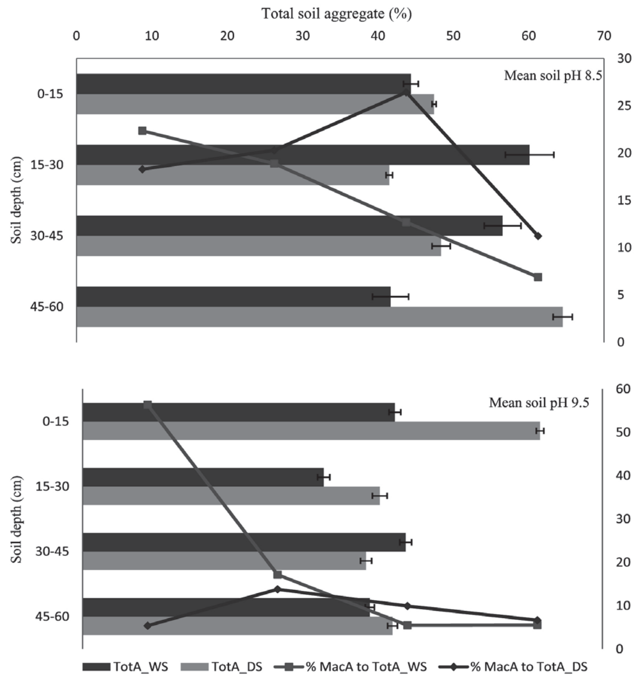

Fig. 1. Soil aggregates in different soil depths at mean pH 8.5 and 9.5 under waterlogged and non- waterlogged conditions.
Depictions: TotA_WS and TotA_DS: Total aggregates under waterlogged and non-waterlogged conditions, respectively; MacA to TotA_WS and MacA to TotA_DS: Ratio of macro-aggregates to total aggregates under waterlogged and non-waterlogged conditions, respectively.

The results showed that the upper layer contain more macro aggregates and decreased as in increased soil depth in the soil profile (Fig. 1). Shreyasi *et al*. (2014) also reported that the macro aggregates decreased with increasing soil depth. The macro aggregates increased from 9.9% at pH 8.5 to 20.3% at pH 9.5 at soil depth 0-15 cm in waterlogged condition. In contrast, in non-waterlogged soil conditions the macro aggregates decreased from 8.7 at pH 8.5 to 2.8% at pH 9.5 at the same soil depth. Under the waterlogged conditions, organic matter decomposition rate was very slow, that might had prevented the decomposition of organic residues, hence hindering in formation of soil aggregation. However, in the waterlogged condition under low pH it helps in improving the soil aggregation. The result showed that the trend of micro aggregates increased with increasing with soil depth (Fig. 1) and the same trend was also reported by Shreyasi *et al*. (2014).

Conclusion

The wide range of total water stable aggregates (27.83-64.52%) were recorded in waterlogged and non-

Table 2. Soil physical indices under waterlogged and non-waterlogged sodic soils

Treatments	Total WSA (%)	Macro A (%)	Micro A (%)	AR	MWD (mm)	GMD (mm)	AS
0-15cm depth							
WL pH 8.5	44.37^{c} ± 0.97	9.92^{b} ± 0.20	34.45^{c} ± 0.81	0.29^{b} ± 0.00	0.34^{b} ± 0.01	0.16^{b} ± 0.02	0.30^{a} ± 0.01
WL pH 9.5	36.05^{d} ± 0.69	20.31^{a} ± 0.41	15.74^{d} ± 0.50	1.29^{a} ± 0.05	0.62^{a} ± 0.01	0.48^{a} ± 0.01	0.31^{a} ± 0.00
NWL pH 8.5	47.44^{b} ± 0.28	8.68^{c} ± 0.28	38.76^{b} ± 0.56	0.22^{b} ± 0.01	0.23^{c} ± 0.00	0.05^{c} ± 0.00	0.29^{a} ± 0.00
NWL pH 9.5	52.80^{a} ± 0.43	2.84^{d} ± 0.26	49.96^{a} ± 0.20	0.06^{c} ± 0.00	0.18^{d} ± 0.01	0.01^{d} ± 0.00	0.26^{b} ± 0.00
Mean	45.16	10.44	34.73	0.47	0.34	0.18	0.29
15 - 30 cm depth							
WL pH 8.5	60.12^{a} ± 3.22	11.36^{a} ± 0.33	48.76^{a} ± 3.06	0.23^{ab} ± 0.01	0.24^{bc} ± 0.01	0.06^{b} ± 0.01	0.25^{d} ± 0.01
WL pH 9.5	27.83^{c} ± 0.70	4.77^{c} ± 0.34	23.05^{c} ± 0.60	0.21^{b} ± 0.02	0.31^{a} ± 0.01	0.10^{a} ± 0.01	0.35^{a} ± 0.00
NWL pH 8.5	41.51^{b} ± 0.43	8.43^{b}± 0.31	33.08^{b} ± 0.56	0.26^{a} ± 0.01	0.25^{b} ± 0.00	0.07^{b} ± 0.00	0.29^{c} ± 0.00
NWL pH 9.5	34.30^{c} ± 0.86	4.73^{c} ±0.08	29.57^{b} ± 0.79	0.16^{c} ±0.00	0.21^{c} ± 0.00	0.02^{c} ± 0.00	0.32^{b} ± 0.00
Mean	40.94	7.32	33.62	0.21	0.25	0.06	0.30
30 - 45 cm depth							
WL pH 8.5	56.54^{a} ± 2.44	7.18^{b} ± 0.27	49.36^{a} ± 2.48	0.15^{b} ± 0.01	0.22^{a} ± 0.01	0.04^{a} ± 0.00	0.26^{b} ± 0.01
WL pH 9.5	37.29^{c} ± 0.69	2.04^{d} ± 0.27	35.25^{b} ± 0.41	0.06^{c} ± 0.01	0.17^{b} ± 0.01	0.01^{b} ± 0.00	0.31^{a} ± 0.00
NWL pH 8.5	48.37^{b} ± 1.21	12.79^{a} ± 0.41	35.59^{b} ± 0.93	0.36^{a} ± 0.01	0.24^{a} ± 0.00	0.05^{a} ± 0.00	0.29^{a} ± 0.00
NWL pH 9.5	32.72^{c} ± 0.64	3.25^{c} ± 0.48	29.47^{c} ± 0.31	0.11^{b} ± 0.02	0.21^{a} ± 0.01	0.02^{b} ± 0.00	0.30^{a} ± 0.01
Mean	43.73	6.31	37.42	0.17	0.21	0.03	0.29
45 - 60 cm depth							
WL pH 8.5	41.67^{b} ± 2.40	2.87^{b} ± 0.17	38.80^{b} ± 2.54	0.08^{b} ± 0.01	0.22^{b} ± 0.00	0.04^{b} ± 0.00	0.31^{ab} ± 0.01
WL pH 9.5	33.15^{c} ± 0.52	1.83^{c} ± 0.06	31.32^{c}± 0.50	0.06^{b} ± 0.00	0.24^{a} ± 0.00	0.06^{a} ± 0.00	0.32^{a} ± 0.00
NWL pH 8.5	64.52^{a} ± 1.27	7.25^{a} ± 0.33	57.27^{a} ± 1.20	0.13^{a} ± 0.01	0.19^{c} ± 0.00	0.02^{d} ± 0.00	0.20^{c} ± 0.00
NWL pH 9.5	35.77^{c} ± 0.56	2.37^{c} ±0.05	33.40^{c} ± 0.60	0.07^{b} ± 0.00	0.21^{b} ± 0.00	0.03^{c} ± 0.00	0.29^{b} ± 0.01
Mean	43.78	3.58	40.20	0.08	0.22	0.04	0.28

Same superscripted letters in a column show that the data are non-significant in a particular soil depth.
Depictions WL- waterlogged, NWL- non-waterlogged

waterlogged conditions, which were affected due to variation in pH of soils. Average total water stable aggregates and their indices were recorded higher in 0-15 cm soil layer and decreased with increase in soil depth. Average macro aggregates were also decreased with increase soil depth, however, in soil with pH 8.5 in waterlogged condition, macro aggregates increased to 9.9 and 11.4% in 0-15 cm and 15-30 cm soil depths, respectively.

References

Choudhury, S.G. Srivastava, S., Singh, R., Chaudhari, S.K., Sharma, D.K., Singh, S.K. and Sarkar, D. 2014. Tillage and residue management effect on soil aggregation, organic carbon dynamics and yield attribute in rice-wheat cropping system under reclaimed sodic soil. *Soil Tillage Res* **136**: 76-83.

Das, B., Chakraborty, D., Singh, V.K., Aggarwal, P., Singh, R., Dwivedi, B.S. and Mishra, R.P. 2014. Effect of integrated nutrient management practice on soil aggregate properties, its stability and aggregate-associated carbon content in an intensive rice-wheat system. *Soil Tillage Res* **136**: 9-18.

Diaz-Zorita, M., Perfect, E., and Grove, J.H. 2002. Disruptive methods for assessing soil structure. *Soil Till. Res* **64**: 3-22.

Kay, B.D. 1990. Rates of change of soil structure under different cropping system. *Advances in Soil Science* **12**: 1-52.

Kay, B.D. 2000. Soil structure: In summer, E.M. (ed.) Handbook of Soil Science. Boca Raton, London, New York: A 229-A 264.

Mostaghimi, S., Young, R.A., Wiltts, A.R. and Kenime, A.L. 1988. Effect of frost action on soil aggregate stability. *T. ASAE* **31**: 435-439.

Oztas, T. and Fayetorbay, F. 2003. Effect of freezing and thawing processes on soil aggregate stability. *Catena* **52**: 1-8.

Piper, C.S. Soil and Plant analysis. Asia Publishing House, New Delhi, India, 1967.

Qiang, M.A., Wan-Tai, Y.U., Shao-Hua, Z.H.A.O., and Lu, Z.H.A.N.G. 2007. Relationalship between water-stable aggregates and nutrients in black soil after reclamation. *Pedosphere* **17 (4)**: 538-544.

Six, J., Elliott, E.T. and Paustian, K. 2000. Soil macroaggregate turnover and microaggregate formation: a mechanism for C sequestration under no-tillage agriculture. *Soil Biol. Biochem* **32**: 2099-2103.

Spohn, M. and Giani, L. 2011: Impact of land use change on soil aggregation and aggregate stabilizing compound as dependent on time. *Soil Biol. Biochem* **43**: 1081-1088.

Tisdall, J.M. and Oades, J.M. 1982. Organic matter and water-stable aggregates in soils. *J. Soil Sci* **62**: 141-163.

Yoder, R.E. 1936. A direct method of aggregate analysis of soil and the study of the physical nature of erosion losses. *J. Am. Soc. Agron* **28**: 337-351.

Zhang, S., Li, Q., Zhang, X., Wei, K., Chen, L. and Liang, W. 2012. Effect of conservation tillage on soil aggregation and aggregate binding agents in black soil of Northeast China. *Soil Tillage Res* **124**: 196-202.

Shouse , P.J., Gerik, T.J., Russel, W.B., and Cassel, D.K. 1990. Spatial distribution of soil particle size and aggregate stability index in a clay soil. *Soil Sci* **149**: 351-360.

Ram, J. Dagar, J.C., Lal, K., Singh, G., Toky, O.P., Tanwar, V.S., Dar, S.R. and Chauhan, M.K. 2011. Biodrainage to combat waterlogging, increase from productivity and sequester carbon in canal command areas of northwest India. *Curr. Sci* **100(11)**: 1673-1680.

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Impact of salt tolerant crop varieties on food grains production under salty environment of India

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ABSTRACT

Numbers of salt tolerant varieties of rice, wheat and mustard have been developed. About 196 ton rice, 129 ton wheat and 6.5 ton mustard breeder and TL seeds of salt tolerant varieties have been produced and distributed by the Central Soil Salinity Research Institute (CSSRI) to various seed multiplication agencies and farmers during a period of 10 years from 2000-01 to 2010-11. Seed multiplication ratio of these salt tolerant varieties at secondary level estimated to be 40 for rice, 20 for wheat and 22 for mustard varieties. These seeds also multiplied at tertiary level, i.e. in the farmer's field at the rate of 1.7 times. The quantity of breeder and TL seeds together estimated to be 68154, 7165 and 182 ton for rice, wheat and mustard varieties, respectively. The overall quantity of these seeds made available to the farmers after multiplying at secondary as well as tertiary level was more than 203 thousand ton during a period of 10 years amounting to 20 thousand ton per year. The area coverage of these varieties was 6.40 million ha during the decade from 2000-01 to 2010-11 out of which 6.13 million ha, was under rice, 193 thousand ha under wheat 82 thousand ha under mustard during the reference period. The total production of rice realized at farm level was 18.40 million ton from these salt tolerant varieties. It was 2.45 million ton higher than the estimated production from the same area being harvested from the prevalent non-salt tolerant rice varieties. Similarly, 484 thousand ton wheat production was obtained during 2000-01 to 2010-11 at national level from the salt tolerant varieties. It was 68 thousand ton more than the replaced varieties of wheat earlier grown by the farmers. In case of salt tolerant mustard varieties, the additional production estimated to be 21 thousand ton during the reference period in the country. Total production of salt tolerant mustard CSSRI varieties was 106 thousand ton as against 86 thousand ton estimated production of local varieties grown by the farmers. The value of additional production due to adoption of CSSRI salt tolerant varieties of rice, wheat and mustard estimated to be Rs 25663 million during the decade from 2000-01 to 2010-11. It is obvious from these estimates that the salt affected salt tolerant varieties of rice, wheat and mustard are providing additional food grains to the tune of Rs 2566 million every year at National level.

Key words: Breeder seed, saline soil, salt tolerant, sodic soil

Introduction

Meeting the increasing demands for food, forage, fibre and fuel will be a pressing challenge for the world community during the years ahead. This will require a larger production of biomass over a shrinking land area. Breeding crop varieties for increased salt tolerance is now considered as promising, energy-efficient and economical approach than major engineering processes and soil amelioration techniques which have gone beyond the limits of marginal farmers. The biological management of salt-affected soils by growing the salt-tolerant varieties has become successful without any chemical amendment. The rice varieties provide 3.5 to 4.5 t ha^{-1} yield in the first year and bring down the original soil pH from 10.2 to 9.9 after the crop harvest. In the second year, the yield goes beyond 4.5 t ha^{-1} and the pH level comes down to 9.7 while in third year, the pH remains around 9.5. Similarly, the EP exchange able sodium percentage (ESP) comes down from 85 to 40. The soil physical characteristics are also improved. By the third year, the field becomes ideal for growing wheat or mustard in the rabi season. The salt tolerant rice, wheat and mustard varieties have become very popular and are being grown in salt-affected soils in many states (Mishra et al., 1997). Central Soil Salinity Research Institute (CSSRI), Karnal has developedsalt tolrent varieties which provide a viable option for the farmers who are growing crops in saline/sodic /water logged environment. The variety technology is quite simple for adoption by farmers. The long-term impact of biological or chemical-cum-biological reclamation is tremendous for increasing productivity with reduced costs, betterment of environment, employment generation and food security. The salt-tolerant crop varieties have lower leaching requirement than salt-sensitive crops and so reduce irrigation cost (Sharma, 2010). Therefore, faster conversion of degraded lands into the production chain with the use of resilient varieties can cover more areas and help for increasing food productivity from these salt affected lands. So production and distribution of salt-tolerant-verities by CSSRI in saline-sodic land can mitigate the major hurdles for crop production.

The Central Soil Salinity Research Institute has developed number of salt tolerant crop varieties namely, CSR10, CSR13, CSR23, CSR27, CSR30, CSR36 of rice; KRL1-4, KRL19, KRL210, KRL213 of wheat; and CS 52, CS 54 and CS 56 of mustard (Gupta and Tripathi, 2010). These varieties have been approved and released by the Central Variety Release Committee, Ministry of Agriculture, Government of India for different salt affected areas of the country. These varieties have considerable direct as well as indirect impact for enhancing agricultural productivity and raising farmers' livelihood in the salty environments. The popularity of first salt tolerant basmati type variety CSR30 is remarkable. The varietal approach is not only economical and simple to adopt but also ensures preservation of the aerial and soil ecosystems. Since the development of these varieties vis-a-vis CSSRI has been producing their nucleus, breeders and truthful labelled (TL) seeds to meet the requirement of National and State organizations as well as private agencies and farmers. However, the direct and indirect impacts of such technologies are not adequately addressed and assessed. Therefore, the study on impact assessment of salt tolerant varieties developed by CSSRI has been undertaken for generating valuable information to the seed producing agencies and also to the policy makers, planners and research managers on various aspects of the production, multiplication and distribution pattern of salt tolerant varieties.

Keeping in view the scope of salt tolerant crop varieties and numerous socio-economic benefits of the technology, it is worthwhile to examine the pattern of breeder and certified seeds production, multiplication of these seeds, area covered under these varieties and yield benefits and impacts of the technology at national level. More specifically, objective of the study were (i) to quantify salt tolerant breeder and TL seeds of different crops produced and distributed by the CSSRI to different seed producing agencies and the farmers; (ii) to estimate multiplication ratio of salt tolerant seeds of different crops by professional seed producing agencies as well as progressive farmers at secondary and tertiary levels; (iii) to estimate total area covered under these varieties and yield benefits accrued by the technology and (iv) to assess economic impacts of the technology at National level.

Material and methods

Results and findings of this paper are based on primary as well as secondary data collected from different sources. An intensive enquiry was made to collect primary data on various aspects of salt tolerant crop varieties produced and distributed to seed multiplication agencies as well as the farmers. The data were recorded for a decade (period) from 2000-01 to 2010-11. Additional associated informations were collected through direct personal interviews with the selected respondents. Data were analyzed using simple statistical tools and techniques to highlight facts and findings of the study.

(i) Selection of area and respondents

In general, states like Haryana, Punjab, Uttar Pradesh, Rajasthan and Gujarat are the targeted area where large quantity of salt tolerant crop varieties developed by CSSRI is being used by the farmers. The Haryana and Uttar Pradesh states were selected purposively for this study to collect farm level data as these states are the major consumers of salt tolerant variety seeds developed by CSSRI. Two district from Haryana namely, Karnal and Kurukshetra and two from Uttar Pradesh namely, Raibarely and Sultanpur were choosen where salt tolerant variety seeds were distributed by CSSRI during a decade from 2000-01 to 20010-11. One block was selected in each selected district, where farmers have been adopted salt tolerant variety seeds of CSSRI. Randomly two villages were selected from each block where salt tolerant crop varieties being used extensively. Finally, a sample of 10 farmers who had applied seeds of CSSRI for at least three years on their farms was drawn from each of the selected village. Thus, a total number of 80 farmers were interviewed from Haryana and Uttar Pradesh.

Actual quantity of nucleus, breeder and foundation seeds was recorded from the records of Crop Improvement Division, CSSRI from 2000-01 to 2010-11 whereas, quantity of TL seeds for same tanure was recorded from the records of Seed Production Unit, CSSRI. In order to quantify production and multiplication of Certified/ TL seeds of salt tolerant crop varieties developed by CSSRI, all the State and Central Government, autonomous and non-government organizations as well as private seed producing agencies like State Seed Farms, State Seed Development Corporations, Land Reclamation Corporations, National Seed Corporation, SFCI, IFFCO (IFDC), Agro Seeds, etc. were communicated for collection of the relevant information.

(ii) Collection of data

The information was collected from primary as well as secondary sources on seed production pertaining to the varieties of different crops developed for salt tolerant environment by CSSRI. The agencies involved in production and distribution of seeds of salt tolerant verities were contacted and interviewed to record actual quantity of the seeds multiplied and distributed to farmers. The Development Departments of the State Governments were also approached to find out quantity of the seeds multiplied and distributed to farmers and other

Table 1. Breeder/ labelled/ certified seeds of all the salt tolerant varieties produced and distributed by CSSRI from 2000-01 to 2010-11

Crop	Quantity (t ha^{-1})	% to total
Rice	196.1	59.15
Wheat	128.9	38.90
Mustard	6.5	1.95
Total	331.5	100.00

1. Seed production

The quantity of breeder and TL seeds of salt tolerant varieties of rice produced and distributed by CSSRI is presented in Table 4. Data indicate that 196 ton seeds of salt tolerant varieties of rice was made available by the institute for various seed multiplication agencies and other stakeholders during a period of 10 years from 2000-01 to 2010-11. The annual average quantity of salt tolerant seeds produced and supplied by CSSRI to the stakeholders estimated about 20 ton. The highest quantity of seeds of CSR 13 variety of rice was 63 ton which constituting 32.13% of the total rice seeds during the reference period followed by rice variety CSR 10 (42 ton), CSR 27 (41 ton) and CSR 30 (39 ton), respectively.

Table 2. State wise distribution of salt tolerant salt tolerant CSSRI seeds of rice varieties (in %)

State	CSR 10	CSR 13	CSR 23	CSR 27	CSR 30	CSR 36	Total
Haryana	40	25	65.05	38.07	87.06	90.79	57.80
Uttar Pradesh	60	50	1.36	0.00	12.04	0.96	20.73
Punjab	0.00	0.00	0.00	0.00	0.90	0.00	0.01
Bihar	0.00	0.00	31.67	13.30	0.00	7.67	8.77
Others	0.00	25	1.92	48.63	0.00	0.58	12.69

stakeholders at their own level. Personal interviews were made for collection of data about the rate of multiplication of seeds at secondary and tertiary levels as well as progressive farmers.

Results and discussion

Total quantity of breeder/ TL-certified seeds produced and distributed during the decade from 2000-01 to 2010-11 is given in Table 1. Data indicate that lion share of these seeds was of rice varieties being 59 percent of the total seed produced. Contribution of wheat seeds was about 39 percent of the total salt tolerant seeds. The state-wise distribution pattern of salt tolerant seeds of rice and wheat is given in Table 2 and Table 3, respectively. The state-wise distribution pattern revealed the fact that about 58 percent of the total rice seeds were consumed in the state of Haryana alone. Uttar Pradesh was the second important state where nearly 21 percent rice seeds was supplied by the CSSRI. Almost half and of the total quantity of salt tolerant wheat seeds was used in Haryana and 44% used in Uttar Pradesh. A small quantity of rice seeds took by Bihar (9%), while some quantity of wheat seeds moved to Rajasthan (5%).

The salt tolerant wheat varieties seeds produced by CSSRI was estimated to be 129 ton from 2000-01 to 2010-11, out of which 67.81 and 32.19% was of KRL 19 and KRL 1-4 variety (Table 5). The institute has initiated seed production of KRL 210 and KRL 213 during the study period. Further more verities were released only in the year 2010. Now these are yet to take momentum at farmers' field. Institute produce 6.46 ton of mustard seed from 2000-01 to 2010-11 The CS 52, CS 54 and CS 56 varieties of mustard contributed 67, 19 and 14% of the total salt tolerant mustard seeds, respectively (Table 6).

Table 3. State-wise distribution of salt tolerant CSSRI seeds of wheat varieties (in %)

State	KRL 1-4	KRL 19	Total
Haryana	54.27	44.24	49.26
Uttar Pradesh	40.56	47.00	43.78
Punjab	1.50	0.40	0.75
Rajasthan	3.29	6.03	4.86
Gujarat	0.38	1.27	0.83

2. Seed multiplication ratio

The seed multiplication ratio of the CSSRI salt tolerant rice varieties at secondary level estimated 40,

Table 4. Breeder/ labelled/ certified seeds of salt tolerant varieties of rice produced and distributed by CSSRI from 2000-01 to 2010-11

Variety	Quantity (ton)	Percentage
CSR 10	42.42	21.63
CSR 13	63.00	32.13
CSR 27	41.08	20.95
CSR 30	39.30	20.02
CSR 23	2.27	1.16
CSR 36	8.07	4.12
Total	196.10	100.00

Table 5. Breeder/ labelled/ certified seeds of salt tolerant varieties of wheat produced and distributed by CSSRI from 2000-01 to 2010-11

Variety	Quantity (ton)	% to total
KRL1-4	41.52	32.19
KRL 19	87.46	67.81
Total	129.00	100.00

Table 6. Breeder/ labelled/ certified seeds of salt tolerant varieties of mustard produced and distributed by CSSRI from 2000-01 to 2010-11

Variety	Quantity (ton)	% to total
CS 52	4.35	67.34
CS 54	1.22	18.90
CS 56	0.89	13.76
Total	6.46	100.00

whereas it was 20 for wheat varieties (Table 7). The seed multiplication ratio of salt tolerant mustard varieties was 22. The seeds of rice, wheat and mustard also multiplied at tertiary level i.e. in the farmer's field. The progressive farmers actively involved in multiplication of the quality seeds in participatory mode. The participatory seed production increases efficiency of the scientific and seed producing agencies (Bellon, 2001) and farmers' knowledge that enables them to be retained effectively in seed production (Grisley and Shamambo, 1993). Research costs can be reduced and adoption rates increased if farmers are allowed to participate in variety testing and multiplication practices (Joshi *et al.,* 1995). In addition, production increases when farmers adopt new varieties identified in participatory research (Witcombe, 1999). These salt tolerant seeds were multiplied at the rate of 1.7 times at tertiary level. Around 154 and 111 ton of rice and wheat seeds were produced at secondary multiplication level when seeds of CSSRI use for seed production. In case of mustard, the total seed multiplied at secondary level was 4 ton because of the fact that only 15% of the breeder seeds used for further multiplication. The quantity of breeder and TL seeds both estimated to be 68154 ton, 7165 ton and 182 ton for rice, wheat and mustard varieties, respectively. The overall quantity of these seeds made available to the farmers estimated about 204 thousand ton during a period of 10 years from 2000-01 to 2010-11. Out of this quantity of seeds, rice salt tolerant varieties contributed 184 thousand tons, wheat 19 thousand ton and mustard 5 thousand ton.

3. Area coverage

The estimated area coverage of the salt tolerant varieties of rice, wheat and mustard during the decade from 2000-01 to 2010-11 was 6.40 million ha. The area covered by salt tolerant varieties of rice was 6.13 million ha.Whereas, wheat salt tolerant varieties covered 193 thousand ha and mustard 82 thousand ha (Table 8).

4. Additional production and benefits generated by salt tolerant CSSRI varieties

The additional production due to CSSRI varieties and benefits realized by salt tolerant seeds from 2000-01 to 2010-11 are presented in Table 8, which portray that the total production of rice realized by the farmers was 18.40 million ton from the salt tolerant varieties. It was 2.45 million ton higher than the estimated production from the same area being harvested from the prevalent non-salt tolerant rice varieties. Similarly, 484 thousand ton wheat production was obtained at national level from the salt tolerant CSSRI varieties from 2000-01 to 2010-11. It was 68 thousand ton more than the replaced varieties of wheat earlier grown by the farmers. In case of salt tolerant CSSRI mustard varieties, the additional production estimated to be 21 thousand ton during the reference period from 2000-01 to 2010-11 in the country. The total production of salt tolerant mustard CSSRI varieties was 106 thousand ton as against 86 thousand ton estimated production of local varieties grown in the same area by the farmers.

The value of additional production due to adoption of CSSRI salt tolerant varieties of rice, wheat and mustard estimated to be Rs 25663 million at National level during the decade from 2000-01 to 2010-11. It is obvious from these estimates that the salt affected salt tolerant varieties

Table 7. CSSRI salt tolerant breeder and truthful leveled seeds multiplied at secondary and tertiary levels from 2000-01 to 2010-11

Name of Crop	Breeder seed produced by CSSRI (ton)	Seed multiplication ratio at secondary level	Certified seed estimated (ton)	TL Seed supplied by CSSRI (ton)	Certified + TL seeds (ton)	Seed multiplied at tertiary level (ton)	Overall quantity of seeds made available to farmers (ton)
Rice	42.50	40	68000	154	68154	115861	184015
Wheat	17.64	20	7054	111	7165	12181	19346
Mustard	2.45	22	178	4	182	309	492
Total	62.59	-	75232	269	75501	128351	203853

Table 8. Area covered and benefits generated by CSSRI salt tolerant seeds from 2000-01 to 2010-11

Name of Crop	Estimated area covered (000 ha)	Total production due to CSSRI seeds (000 ton)	Estimated production by replaced variety in the same area (000 ton)	Additional production due to CSSRI varieties (000 ton)	Value of additional production (Rs in million)
Rice	6134	18402	15948	2454	24535
Wheat	193	484	416	68	758
Mustard	82	106	86	20	370
Total	6409	18992	16450	2542	25663

of rice, wheat and mustard, developed by CSSRI, are providing Rs 2566 million every year additional income to the country. The contribution of rice varieties under reference in the total value of the additional production made by salt tolerant varieties was more than 95 percent which underlines wide scope of rice salt tolerant varieties in salt affected environment.

Conclusions

The CSSRI has developed number of salt tolerant varieties of rice, wheat and mustard which have made considerable impact on agricultural productivity and raising farmers' livelihood in the harsh salinity affected environments. About 196 ton rice, 129 ton wheat and 6.5 ton mustard breeder and TL seeds of salt tolerant varieties have been produced and distributed by the CSSRI to various seed multiplication agencies, farmers and other stakeholders during a period of 10 years from 2000-01 to 2010-11. Thus, the CSSRI made available 332 ton per annum total salt tolerant seeds to the farming community of India who are operating salt affected land. The seed multiplication ratio of CSSRI salt tolerant varieties at secondary level estimated to be 40 for rice, 20 for wheat and 22 for mustard varieties. These seeds also multiplied at tertiary level i.e., in the farmer's field at the rate of 1.7 times. The CSSRI seeds produced by secondary multiplication level estimated 154 ton for rice and 111 ton for wheat and 4 ton for mustard varieties. The quantity of breeder and TL seeds together estimated to be 68154 ton, 7165 ton and 182 ton for rice, wheat and mustard varieties, respectively. The overall quantity of these seeds made available to the farmers after multiplying its at secondary as well as tertiary level was more than 203 thousand ton during a period of 10 years from 2000-01 to 2010-11, which amounting to 20 thousand ton per year.

The estimated area coverage of these varieties was 6.40 million ha during the decade from 2000-01 to 2010-11. The total production of rice at farm level was 18.40 million ton, wheat 484 thousand ton and mustard 21 thousand ton from the salt tolerant CSSRI varieties. The rice and wheat production was 2.45 million and 68 thousand ton higher than the estimated production from the same area being harvested from the prevalent non-salt tolerant varieties of these crops. Total production of mustard due to salt tolerant CSSRI varieties was 106 thousand ton as against 86 thousand ton estimated production of non-salt tolerant varieties grown earlier by the farmers. The additional income from CSSRI salt tolerant varieties of rice, wheat and mustard estimated Rs 25663 million during the decade from 2000-01 to 2010-11, which is interpreting to Rs 2566 million every year at the National level.

References

Bellon, M.R. 2001. *Participatory Research Methods for Technology Evaluation*. A Manual for Scientist Working with Farmers. Mexico, D. F. CIMMYT pp. 93.

Grisley, W. and Shamambo, M. 1993. An analysis of adoption and diffusion of Carioca beans in Zambia resulting from an experimental distribution of seed. *Expl. Agriculture* **29:** 379-386.

Gupta, S.K. and Tripathi, R.S. 2010. Profile of Central Soil Salinity Research Institute Karnal, a publication of CSSRI, Karnal 132001, *http://cssri.nic.in/cssriprofile.pdf.*

Joshi, K.D., Rana, R.B., Subedi, M., Kadayat, K.B. and Sthapit., B.R. 1995. Effectiveness of participatory testing and dissemination programme: a case study of Chaite Rice in the western hills of Nepal. LARC working paper No. 95/49. Pokhara, Nepal: Lumble Agricultural Research Centre.

Mishra, B., Singh, R.K. and Senadhira, D. 1997. Enhancing Genetic Resources and Breeding for Problem Soils. In *IDRC: Resources: Books: Catalogue, Using Diversity: Enhancing and Maintaining Genetic Resources On-Farm,* edited by Louise Sperling and Michael Loevinsohn, IDRC 1997, ISBN 0-88936-833-3, *www.idrc.ca/library/document/104582/mishra.html.*

Sharma, S. K. 2010. *Success Stories on Development, Spread and Impact of Salt Tolerant Varieties of Rice, Wheat and Mustard in India,* Central Soil Salinity Research Institute, Karnal-132001, *www.plantstress.com/Files/Salt_India.pdf.*

Witcombe, J.R. 1999. Do farmer participatory methods apply more to high potential areas than to marginal ones. *Outlook on Agriculture* **28:** 43-49.

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Salinity ingress in coastal Gujarat: Appraisal of control measures

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ABSTRACT

Land degradation due to climatic vagaries like erosion, sea ingress resulting in salty lands and industrial pollution add vows to the agricultural sector, mainly because of lowered crop production. Deterioration of agricultural lands due to physical and chemical processes necessitate to identify strategies for their reclamation, *in-situ* resource conservation, enhancing water availability through rainwater harvesting, arresting salinity ingress in coastal areas, improving the ground water situations, searching for stress-tolerant, low water requiring and high yielding crops etc. The problems of environmental degradation in Gujarat state are as diverse and complex as the ecological fabric of the state. Soil and water salinity problems are essentially multi-sectorial and are complex in nature. Excessive withdrawal of ground water in coastal region has led to the intrusion of seawater leading to salinisation of ground waters and agricultural lands, pollution of drinking water supplies, thus hampering over all agricultural production.

The coastal areas of Gujarat especially the villages lying within 20-25 km from the seashore are suffering from the problem of salinity ingress. Most of the rivulets that drain this region are seasonal at best and their water does not last beyond monsoon. Water storage structures like ponds, which get water from these rivers, also dry up as early as October. This problem of water shortage has worsened over the last few years because of the cultivation of water intensive crops like Sugarcane, Banana, Betel nut Leaves and other field crops. This has had far reaching implications for both household and agricultural uses of water as the availability of fresh water has steadily declined. In order to circumvent this problem, several interventions to mitigate salinity in coastal areas were taken up by Gujarat State Land Development Corporation, Gandhinagar that comprise (1) Construction of reclamation bund for arresting ingress of sea water and also to conserve rain/fresh water for crop production; (2) Water conservation measures like farm ponds, dug out ponds, earthen water harvesting structures, deepening of village ponds, check dams, percolation tanks, field bunding, contour bunding, tidal regulators, etc., mainly to conserve as much fresh water as possible for irrigation purposes. Analysis of different interventions in coastal areas of the districts comprising Valsad, Surat, Bharuch, Vadodara, Anand, Bhavnagar, Jamnagar, Porbandar, Amreli, Rajkot, Junagadh, Kutch and Jamnagar indicated that:

- Increase in crop yields mainly resulting from improved ground water table, water quality and use of the fresh water harvested in water storage devices for providing irrigation at strategic times of crop growth. Paddy showed increase in order of 60 per cent followed by sugarcane (33 %) while kharif and rabi pulses showed 41 and 37 per cent increase, respectively. Both rabi and summer vegetables showed about 35-40 per cent increase indicating the overall agricultural improvement resulting from the interventions.
- Stored surface water brought additional area under cultivation with less salt tolerant and highly remunerative crops
- Sea water ingress on to the agricultural land was found curtailed by the long reclamation bunds constructed
- Improved sub-soil water quality in terms of pH and EC was primarily due to ground water recharging.
- Fallow lands have been brought under cultivation in *Kharif* due to soil and water conservation measures likes field bunding, land leveling and land shaping.
- Creation of supplementary irrigation facility through water harvesting structures, percolation tank and farm pond etc has brought additional area under cultivation.

Thus, from the interventions it is evident that water being an important constraint, its conservation and judicious use has become a clear possibility in the coastal Gujarat which finally resulted in increased cultivated area, household income and improved employment generation.

Key words: Coastal saline soils; sea water ingress; water conservation

Introduction

The economic reforms commenced in 1991 have successfully put the economy in higher growth orbit with more than 8 per cent growth rate in Gross Domestic Product (GDP) especially during the recent years. Agriculture sector which accounts for 30 per cent of total GDP in the beginning of the reforms phase failed to maintain its pre-reform growth. On the contrary, it witnesses a sharp decline in growth after mid-90s. India has agrarian economy and a sustained and wide spread agricultural growth is a primary requisite for its development since more than 60 per cent of the population depends on agriculture for livelihood. Constant increase in population warrants intensive agriculture to meet the food, fuel, fodder, fibre and timber needs. This has also led to decline in lands for arable farming. Land degradation due to climatic vagaries like erosion, sea ingress resulting in salty lands, industrial pollution further add vows to the agricultural sector, mainly because of lowered crop production (Gururaja Rao *et al.*, 2003). The limitation of geographical area has compelled the Government to try to enhance the crop production through wasteland reclamation. Deterioration of agricultural lands due to physical and chemical processes necessitate to identify strategies for their reclamation, *in-situ* resource conservation, enhancing water availability through rainwater harvesting, arresting salinity ingress in coastal areas, improving the ground water table situations, searching for stress-tolerant, low water requiring and high yielding crops etc.

It is reported that about 6.73 Mha of land is salt affected in India of which 2.22 Mha is present in Gujarat State. Of this, about 60 per cent area is affected by coastal salinity problems. The problems of environmental degradation in Gujarat state are as diverse and complex as the ecological fabric of the state. While some of the problems are widespread and operate over long term, the others are mainly localised and more intensive in their impacts. Soil and water salinity problems are essentially multi-sectorial and are complex in nature. Vast areas are in imminent danger of turning barren and production and productivity have simply declined due to secondary salinisation. Soil salinity problems are further compounded where the ground water is highly saline and such areas *by and large* remain barren for want of economically feasible technological interventions and thereby affecting the livelihood of the farmers because of low productivity of the existing farming practices. The adverse effects of salinity have put the food and nutritional security at stake while creating environmental pollution and affecting health (Gururaja Rao *et al.*, 2001, 2013).

Since degraded natural resources like soil and water and low soil fertility are the major constraints to increase and stabilize agricultural production, efforts must be made to conserve the vital resources. Rainwater management and the implementation of soil conservation programme holds the key to an ecologically balanced improvement in the quality of rainfed land. Over-exploitation of ground water resulting in depletion of ground water table makes the present cropping systems unsustainable. Excessive withdrawal of limited ground water in coastal region has led to the intrusion of seawater leading to soil salinisation, pollution of drinking water supplies and large-scale migration of people from the affected areas. The beneficial effects of rain water conservation and ground water recharge have already been reported (Gururaja Rao *et al.*, 2010; Jadav *et al.*, 2010)).

Impact of salinity/ sodicity on crop productivity

The State is sharing the longest coastal line in the country i.e. 1600 km out of which Kutch and Saurashtra cover about 1125 km which has adversely affected the ground water by sea water ingress. Every year on an average 0.5 to 1.0km distance from the coastline is affected by sea water ingress. Thus about 5 to 7.5 km wide strip of the inland area has been rendered saline till now and water quality has been deteriorated to more than 2000 ppm of TDS in an area of 100 km^2 (Gururaja Rao *et al.*, 2013). The State has as many as 15 out of total 19 districts with large areas under the effect of salinity where local ground water development is not economically possible (Gururaja Rao *et al.*, 2013). In many areas of North Gujarat, the ground water draft is more than ground water recharge. This has resulted in lowering water levels, known as ground water mining. This decline in water levels has led to

- Drying up of Open wells (shallow wells).
- Higher input costs due to drilling of deep tube wells
- Deterioration of ground water quality resulting in aggravation of problems of salinity.
- Increase in hardness, fluoride and nitrate of ground waters.
- Drastic change in the natural gradient of water in the vicinity of the sea and intrusion of saline water in to the inland area.
- Pumping of water from deep strata has increased the demand of electricity and thus the cost of consumption.

The Study

In order to meet the ever-increasing demands of the growing populace and livestock needs, the Gujarat State Land Development Corporation Ltd., (GSLDC), Gandhinagar (Govt. of Gujarat), through a State Plan Scheme has taken up salinity control/mitigation measures in coastal Gujarat giving major emphasis on arresting sea water ingress in the coastal areas, building fresh water harvesting structures in the areas just away from the coast and soil and crop management interventions for improving crop and forage production.

The major problems prevailed in coastal Gujarat comprise (1) Prevalence of salinity in areas subjected to tidal/sea water ingress; (2) Areas with shallow water table with saline ground water; (3) Water logging/flood situations during monsoon; (4) Inadequate drainage measures; (5) inadequate good quality water and (6) Poor socio-economic situation of the populace inhabiting these areas. The Agency undertook various interventions mainly to mitigate the salinity hazards through conservation, harnessing and developing land and water resources, the two pillars for agricultural production. The specific aspects given major focus comprise of

- Arresting salinity ingress from the sea on to the main land
- Harvesting important natural resource like rainwater in farm ponds
- Conserving rainwater on the other side of the reclamation bund in depressions/other water bodies like ponds etc.,
- Ground water recharge to augment the water table and improve the water quality,
- Providing life saving irrigation facilities for the farmers in the rabi season
- Arresting/checking siltation and soil erosion
- Increase the food, fodder and fuel wood production
- Conserving productive agricultural land from becoming saline
- Increase in area under irrigated farming through water harvesting structures
- Generation of rural employment
- Improve the socio-economic condition of the people including small and marginal farmers and land less labourers
- Increase community awareness on the possible beneficial effects of the interventions

Mitigation of salinity hazards

Soil and water conservation measures

Both agronomic (contour farming, mulching, tillage, strip cropping and mixed cropping) and engineering measures (reclamation bunds to arrest ingress, contour bunding, field bunding, land leveling, water conservation strategies) are deployed, depending upon soil and agro climatic situations. Agronomic measures are adequate for 3-4% slopes and engineering measures are required for more than 4% sloping area.

Development of catchment area and storing runoff water for recycling

Government of Gujarat has shown awareness of the problem of salinity right from the early 1970s, when the groundwater in the coastal areas of Saurashtra and Kutch showed alarmingly rising salinity content. Over withdrawal of groundwater as compared to its recharge potential has led to seawater intrusion all along the coast, which increased the salinity of land and water in the region. The salinity caused many problems like shortage of drinking water, reduction in cropped area, crop yields, migration of people from the region and health hazards for people and livestock.

Evaluation of different mitigation measured taken up by the GSLDC was done by CSSRI, RRS, Bharuch through

1. Survey, enumeration and assessment of different interventions taken up by GSLDC in the coastal region by collecting primary and secondary data (from GSLDC)
2. Data base generation on soil and crop aspects (based on the pre-implementation of interventions)
3. Collection of soil and ground water samples and their analysis to assess the post-implementation impacts
4. Collecting feedback from the farmers/beneficiaries on the benefits of the interventions

Observations and discussion

Rainfall distribution

The data on rainfall during 2006-2012 (Table 1) indicate that 2009, 2011 and 2012 as rain deficit years in all the coastal districts except Navsari and Valsad, which had received relatively good rainfall. Even the heavy rainfall zone covering Valsad, Navsari and Surat showed significant drop in rainfall during 2012, indicating the probable occurrence of dry periods. Kutch and Porbandar districts had received the least rainfall during 2012.

Annual rainfall in the coastal areas varied much with space and time. Kutch region received 244 mm of rain fall in 2012 against decade average of 378 mm during 2002-2011, which amounted to about 64 per cent of decade rainfall. North Gujarat region received 539 mm of rainfall in 2012 against decade average of 665 mm during 2002-2011, which amounted just 81 per cent of decade rainfall. East Central region received 660 mm of rainfall in 2012 against decade average of 807 during 2002-2011, which amounted just 82 per cent of decade rainfall. Saurashtra region received 367 mm of rainfall in 2012 against decade average of 648 mm during 2002-2011, which amounted just 57 per cent of decade rainfall. South Gujarat region received 978 mm rain in 2012 against the decade average of 1359 mm during 2002-2011, which

Table 1. Annual Rainfall (mm) Distribution in Coastal Districts of Gujarat during (2006 – 2012)

Coastal Districts	2006	2007	2008	2009	2010	2011	2012	Average during 1999-2008
Ahmedabad	941	864	738	358	1027	612	458	730
Amreli	820	1061	706	498	829	689	350	673
Anand	1014	876	783	352	826	735	625	728
Bharuch	915	900	759	390	876	634	504	713
Bhavnagar	732	993	708	377	745	584	384	637
Jamnagar	766	1173	642	816	1505	859	379	622
Junagadh	1003	1586	1122	1167	1501	1070	425	873
Kutch	671	557	338	473	862	666	244	361
Navsari	2064	1733	2185	1382	1923	1904	1168	1959
Porbandar	970	1316	661	1372	1653	937	232	674
Rajkot	843	1046	788	538	1123	851	350	622
Surat	2030	1554	1552	1377	1552	1393	926	1479
Valsad	2426	2245	2333	1842	2343	2276	1793	2308

amounted just 72 per cent of decade rainfall. The entire Gujarat state received 576 mm rain in 2012 against 798 mm of decade rainfall with 72 per cent of decade rainfall.

The narrow coastline of Saurashtra and Kutch has long been known as a very fertile tract. The erratic rainfall compelled the people to go for groundwater use to meet the irrigation needs. The electric pumps increased the efficiency of groundwater extraction and accelerated the intensity of irrigation. This resulted in a decline in the freshwater table ultimately paved way for the intrusion of seawater into primarily alluvial aquifers. Various talukas affected by salinity in Gujarat state are given Table 2 (CSSRI, RRS Report 2013).

Table 2. Talukas Affected by Sea Water Ingression in Gujarat

District	Taluka
Amreli,	Jafrabad, Rajula
Anand	Khambhat, Tarapur
Bharuch	Amod, Jambusar, Hansot, Vagra
Bhavnagar	Mahuva, Talaja, Vallabhipur, Ghogha, Bhavnagar
Jamnagar	Jodiya, Kalyanpur, Jamnagar, Khambhalia, Dwarka
Junagadh	Mangrol, Una, Veraval, , Kodinar, Kutiyana, Malia
Rajkot	Malia, Morbi
Surat	Olpad, Choryasi
Valsad	Umargaon, Valsad

Salinity menace in coastal Gujarat is a combination of natural and anthropogenic factors which have the potential to aggravate the problem further. But these factors are also closely linked to land and water management scenario within the state involving both macro and micro level issues.

The interventions undertaken by them are grouped into three categories i.e., (1) Construction of reclamation bund for arresting ingress of sea water and also to conserve rain/fresh water for crop production activities; (2) Water conservation measures like farm ponds, dug out ponds, earthen water harvesting structures, deepening of village ponds, check dams, percolation tanks, nala plugging, field bunding, contour bunding, tidal regulators, etc., mainly to conserve as much fresh water as possible for irrigation purposes and (3) soil and crop management aspects covering land leveling/ smoothening, green manuring, amendment application, horticulture and forestry. The activities undertaken in the entire project are purely on need based and location specific with an aim to get maximum benefits for the local dwellers.

Physical structures – as possible mitigation measures

Various physical structures such as reclamation bund, check dams, farm ponds, recharge tanks, dug out ponds, peripheral bunds are some of the physicl structures that were developed according to the prevailing situations in the coastal districts. Various designs of physical structures are given in Fig. 1a-1c.

The reclamation bunds, while arresting the sea water intrusion to the main land also provided an opportunity to harvest rainwater in the dugout pits (which are also converted into water harvesting bodies), to promote low water requiring crops and some vegetables in Bharuch district (Fig. 2). Reclamation bund measuring 3290 m, peripheral bunds 1069 m, contour bunding of 2241 m were the major activities taken along with good surface drainage and spreading channels in the coast.

Because of the rain water conservation and arresting of sea water ingress, there was a significant increased in crops yields when compared to the pre-implementation phase. Data indicate (Fig. 3) the beneficial effects of the

Fig. 1a. Physical structures to arrest sea ingress: Reclamation bunds (earthen) and check dams

Fig. 1b. Physical structures to arrest sea ingress: Reclamation bunds (cement) and check

Fig. 1c. Physical structures to harness rainwater: Farm ponds and dugout open wells

Fig. 2. Arresting sea water ingress and water conservation for cultivation in Bharuch district

interventions in the post-implementation phase. Increase in crop yields in ground nut, cotton, bajra, til, summer and kharif paddy, jowar, wheat, pigeon pea and onion were noticed in the post-implementation phase across the districts suggesting beneficial effects of interventions that resulted in minimisation of salinity ingress (CSSRI RRS, Bharuch Report 2012).

Effect of salinity mitigation measures on crop performance:

The salinity mitigation measures and water harvesting measures in the coastal districts has resulted in significant increase in crop yields over the pre-implementation crop yields. Of all the crops, across the coastal districts, Ground nut, paddy, pigeon pea, gram, onion, wheat and sapota gave higher yields, in response to irrigation suggesting that there is ample scope for getting better crop yields with water conservation measures (Fig. 4).

Ground water issues

Water conservation has enabled the farmers in the coastal districts to maintain the agricultural activity. It was observed that augmentation of groundwater in the artificial recharge structures act as an incentive for

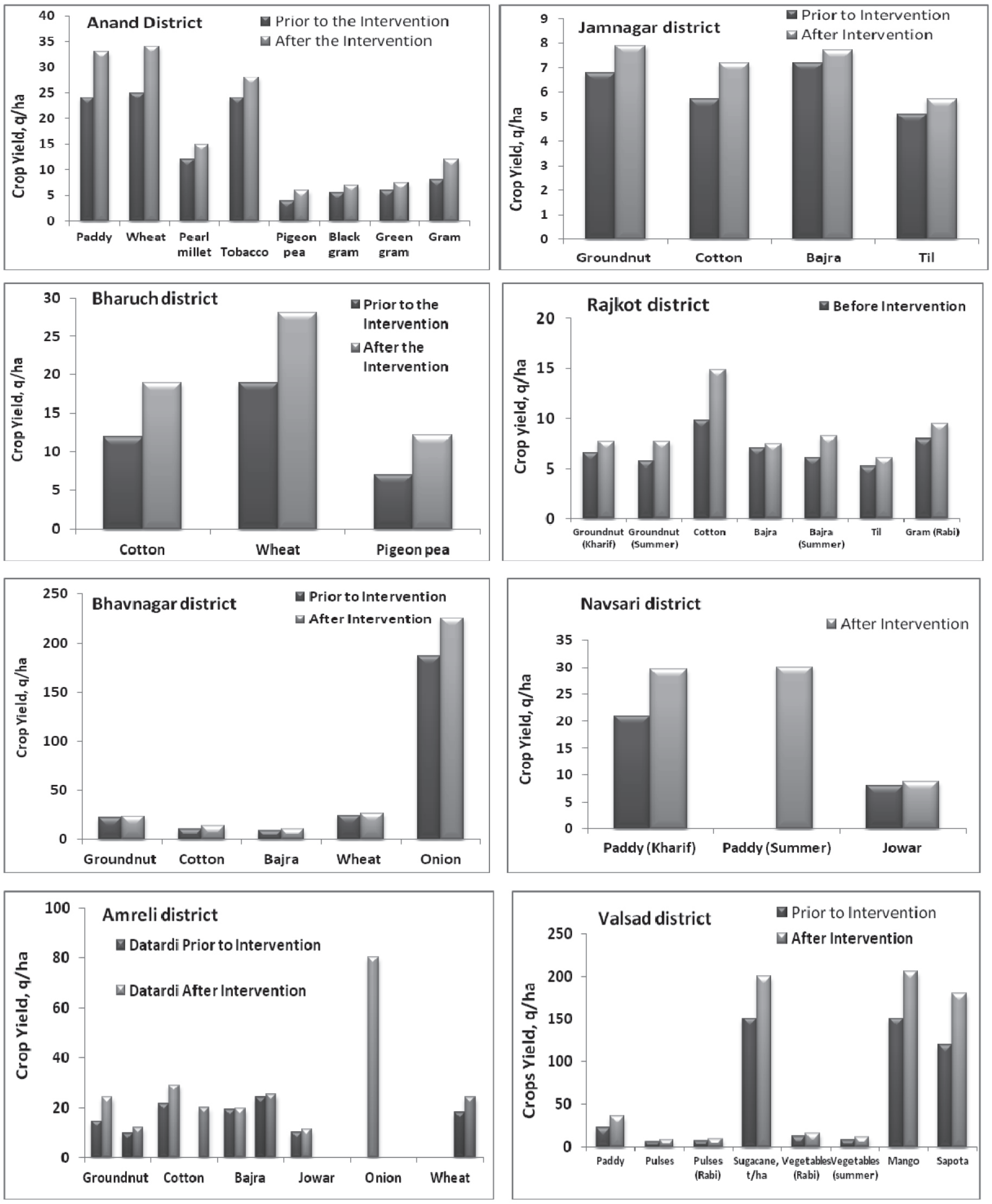

Fig. 3. Effect of salinity mitigation measures on crop yield in different coastal districts of Gujarat

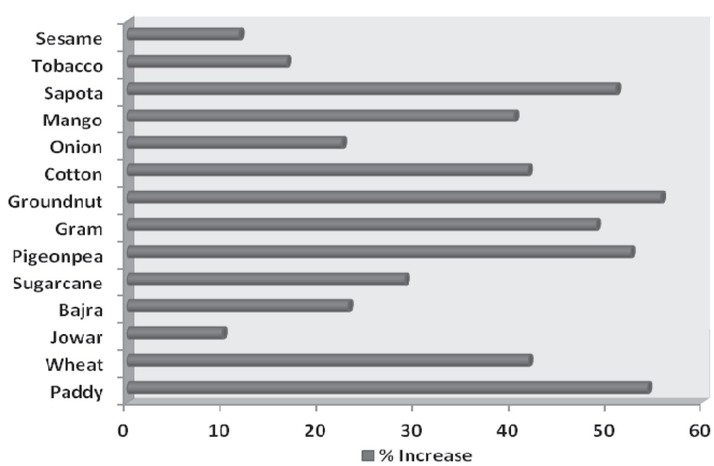

Fig. 4. Increase in crop yields as influenced by salinity mitigtion measures in in coastal districts of Gujarat

Fig. 5. Check dam (Kachhchh) and farm pond (Rajkot) with stored rain water during February-April period (onset of summer) provided irrigation water needs

additional agricultural activity in spite of salinity problems. Ground water levels during the pre-implementation (pre-monsoon period) of the scheme were below in the study areas. With the implementation of the scheme, the water table levels rose because of the recharge structures viz., percolation tanks, earthen water harvesting structures, check dams and other storage devices developed in different regions. Data collected on ground water table during pre and post monsoon phases (Fig. 5) indicated the recharge structures improved ground water status in all the regions more so in Saurashtra region, which has become a boon to the farmers, who could provide more irrigations to the crops. The significant impact of these devices was clearly shown in Kachhchh Rajkot and Jamnagar districts, where the water could be seen flowing in the check dams (Kutch district) or stored in the farm ponds (Rajkot district). The ground water table levels were also found to increase in other districts, which enabled the farmers to meet their water needs. The stored pond water also provides drinking water for livestock.

Ground water table depth

The ground water table depth from each district recorded by the implementing agency was collected and further recorded during the survey and valuation phase. Data on water table depth, is given in Fig. 6 . The data indicated that water table depth during pre-monsoon period varied from 6.8 m in Jamnagar to 34.8 m Kachhchh districts respectively. Deep water tables were noticed in Kachhchh, Navsari, Rajkot, Junagadh and Bhavnagar districts. Due to rain water harvesting and interventions implemented, the water table depth improved significantly and ranged from 4.7 m in Jamnagar to 22 m in Kachhchh indicting the beneficial effects of interventions. Water table depths improved by 32.3, 46.4, 58.2 and 69.1 percent in the post-monsoon period over the pre-monsoon in Navsari, Rajkot, Kachhchh and Junagadh districts, respectively. Higher recharge in Navsari is attributed to its location in the high rainfall zone in South Gujarat. In other districts water tables improved between 20 to 33 per cent. Increase in ground water table depth during post-monsoon period (after the implementation of interventions) with concomitant drop in ground water salinity and pH played an important role in irrigation water needs with better quality of water.

Ground water quality

The ground water quality in terms of salinity (EC) and pH (Fig. 7a & 7b) also showed significant improvement in that, the EC values have gone considerably down in the post-implementation phase. The improved quality of water and prolonged availability of ground water thus has become a boon to the water-scarce areas. This enabled the farmers to provide additional irrigation and thus additional crops could be taken up.

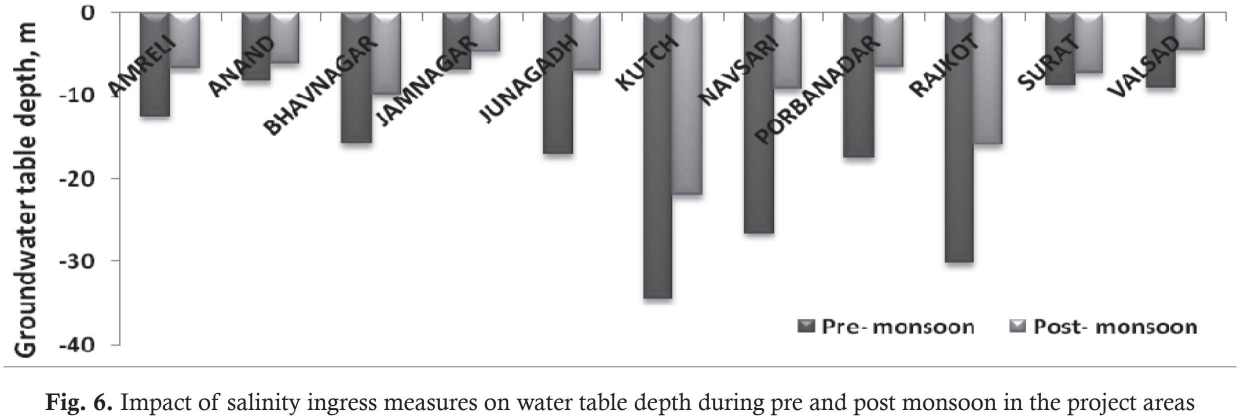

Fig. 6. Impact of salinity ingress measures on water table depth during pre and post monsoon in the project areas

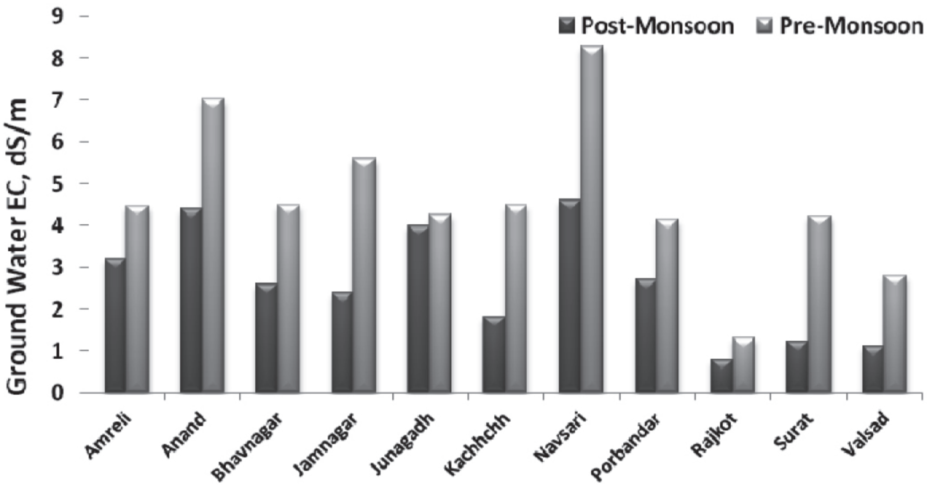

Fig. 7a. Impact of salinity ingress measures on water quality (EC, dS/m) in different districts

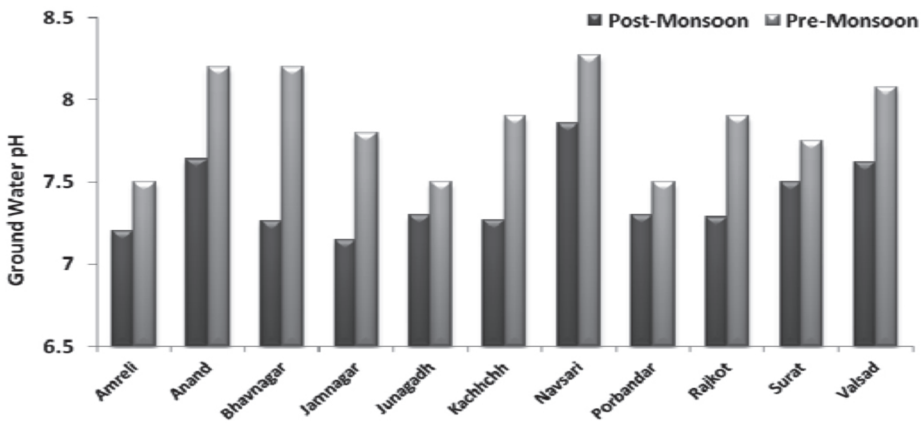

Fig. 7b. Impact of salinity ingress measures on water quality (pH) in different districts

Ground water pH also showed significant decrease in all the location in the post-implementation phase.

There was a change in ground water table depth and quality due to groundwater recharge. Ground water salinity ranged from 1.8 to 8.2 dS/m prior to implementation of mitigation measures and the highest salinity was noticed in Navsari and Anand districts. Salinity mitigation measures resulted in lowering of salinity, the values ranging from 0.8 to 4.6 dS/m. There is a decline of 43.1 per cent and in and 36.7 per cent in ground water salinity of Navsari and Anand districts, respectively. Similar observations were recorded in ground water pH. Even in other districts, the interventions have brought down the ground water salinity.

Performance and impact of different salinity ingress interventions

Interaction with farmers, villagers and other user agencies on the overall performance salinity mitigation measures taken up by GSLDC indicated that the interventions are immensely effective in addressing the issues. Majority of the respondents i.e., about 80 per cent indicated the interventions as very good and less than 3 per cent only indicated that the interventions were satisfactory (Fig. 8). Of all the interventions, water conservation measures such as check dams, farm ponds, water harvesting structures, percolation tanks and other in situ water conservation interventions like contour bunding, Field bunding, land leveling and smoothening have received wider acceptability and their usefulness in meeting out the water needs of the villagers/farmers. Reclamation bund which was built to mainly arrest the salinity ingress, in many areas has bout found quite effective in South Guajrat (Bharuch, Anand, Navsari and Valsad districts) followed by water harvesting structures in Saurashtra and Central Gujarat. *In situ* water harvesting measures like contour bunding, field bunding, land leveling have been found quite effective in conserving moisture that helped in the agricultural activities.

Impact of the salinity mitigation measures

Apart from the phenomenal life giving importance, water remarkably contributes in domestic and industrial activities. Since India is originally a land of farmers and even today, agriculture remains a prime source of

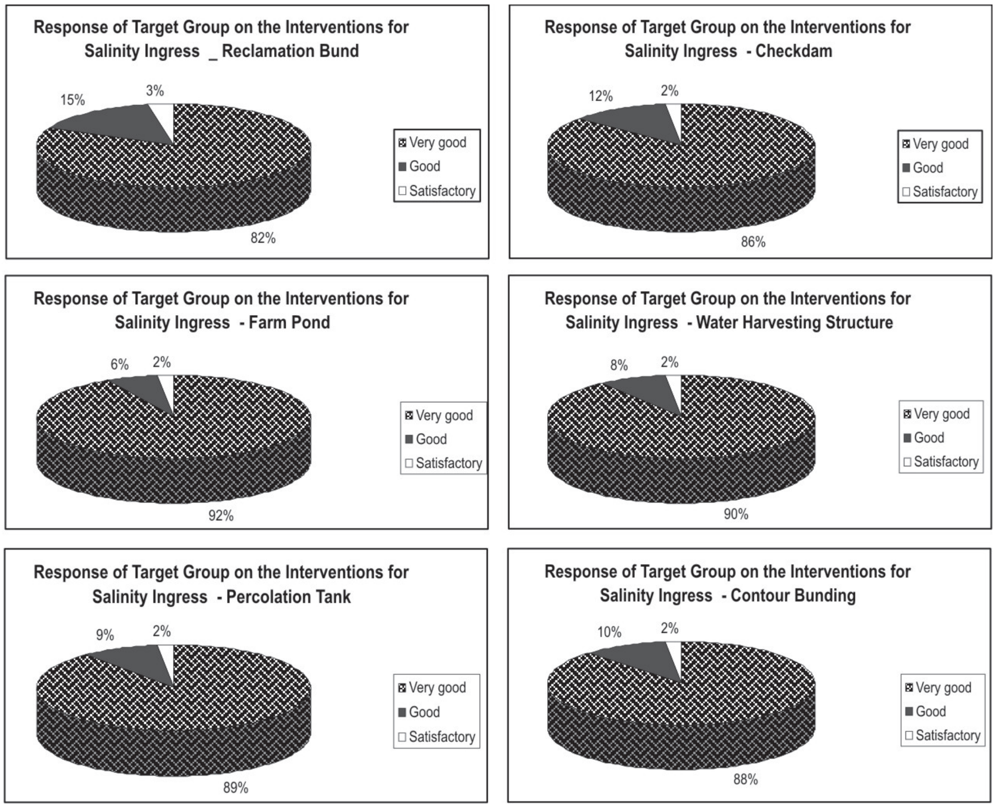

Fig. 8 . Response from farmers/villagers (Target group) on different interventions taken for mitigating salinity ingress in the coastal areas of Gujarat

livelihood among the masses, the abstraction of water for irrigation and other agriculture usages remains a must; needless to mention its importance for domestic water supply and industrial production. Water has been described as "the elixir of life and cleanser of sins". In other words, mankind cannot do without water. Unfortunately, with a galloping population growth, urbanization and ever-increasing demand on it, water resources in the world over are fast depleting. The need for water conservation has therefore become imperative. Ground water is an essential and vital component of our life support system. The ground water resources are being utilized for drinking, irrigation and industrial purposes. There is growing concern on deterioration of ground water quality due to geogenic and anthropogenic activities. Water is most crucial resource for sustainable agricultural production in the dry land rainfed areas. However, the major part of the rainwater coming over the farmer's fields in these areas goes away unused as runoff. Any intervention that helps in its conservation either in open bodies or through ground water recharging thus assumes significance. During the course of the study, the team held discussions at length with the beneficiaries and other agencies to find out the impact of the interventions implemented by GSLDC in the project sites on increase in the cultivated area, possible employment generation, household income and its effect on population migration (Fig. 9). The information gathered from the respondents revealed the following;

Cultivated area: In the project area, cultivated area increased from 6.78 per cent in Porbandar to 15.9 per cent in Kutch district. Most districts recorded increase of more than 10 per cent. The sole factor responsible for this is better ground water recharge, its prolonged availability and also improved water quality, which enabled farmers to bring in additional area under locally grown crops.

Employment generation: This enhanced water availability and increased cultivable area due to the interventions, while improving the agricultural scenario in the region also resulted in additional agricultural employment that ranged from 5.5 (Bhavnagar) to 12.2 per cent (Kutch). The simple reason for this in Kutch district which used to be a water scarce area is mainly ascribed to the check dams and other water harvesting structures that helped the farmers in conserving water which paved a way for bringing new area in agriculture, definitely a positive factor in the region.

Household income: Amreli district which had large number of check dams as water conservation devices helped the farmers to go in for cash rich crops, like Bt cotton, castor, along with other oil seeds resulted in better economic returns. Increased agricultural activities also helped increase in house hold income, particularly in Kutch and other areas. Nevertheless, in other areas also the interventions brought out some increase in household income that helps the farmers to meet their needs.

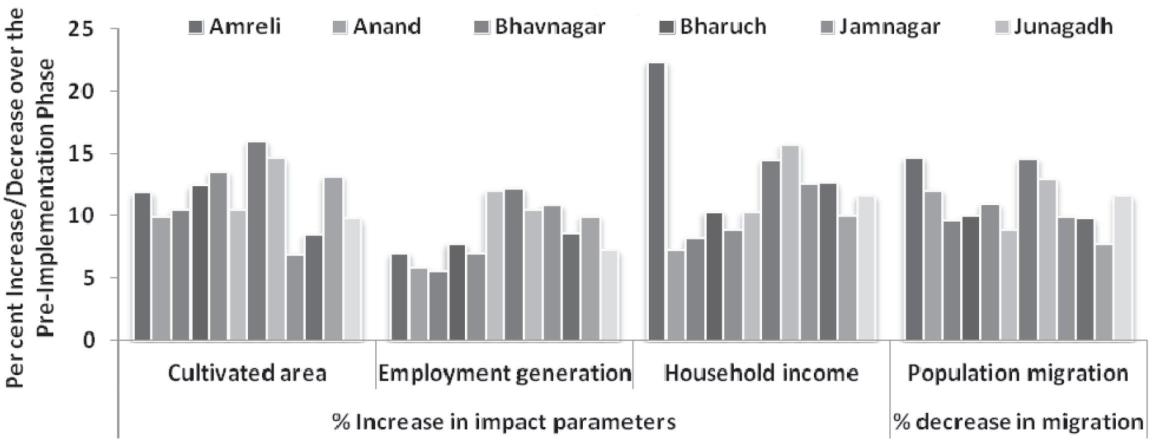

Fig. 9. Overall impact of salinity mitigation measures on cultivated area, income and other factors.

Population migration: Lack of adequate natural resources like water that impair agricultural production compelled the movement of people from coastal areas in search of their livelihood. Any intervention that meets the requirement of important resource like water, which has plethora of uses in sectors like agriculture that constitutes the backbone of the income of the rural populace, definitely minimizes the migration of the people. This is clearly evident from the studies wherein Amreli and Kutch districts showed least of migration about 14.4 per cent. In all other districts, migration of people has also reduced due to continued work opportunity in agricultural sectors. Thus, the interventions implemented in the coastal regions helped in minimizing salinity, increasing ground water recharge and water availability for agricultural crops is of paramount importance in the overall development of the region.

The salinity mitigation measures taken up in coastal Gujarat state resulted in significant increase in crop yields were noticed mainly resulting from improved ground water table, water quality and use of the fresh water harvested in water storage devices for providing irrigation at strategic times of crop growth. South Gujarat region, being considered as horticultural hub, got tremendous boost, mainly resulting from adequate water availability during summer months as well as in rabi season. The series of discussions held with farmers to have their feedback on the derived benefits clearly indicated agricultural growth in the coastal areas is mainly due to water conservation. However, they were of the opinion that many such interventions need be given priority for the overall improvement in agricultural activities.

Water conservation strucatures such as check dams, farm ponds, water harvesting structures, percolation tanks and other in situ water conservation interventions like contour bunding, field bunding, land leveling and smoothening have received wider acceptability and their usefulness in meeting out the water needs of the villagers/ farmers. Reclamation bunds which were built to arrest the salinity ingress, in many areas have been found quite effective in South Guajrat (Bharuch, Anand, Navsari and Valsad districts) followed by water harvesting structures in Saurashtra and Central Gujarat. *In situ* water harvesting measures like contour bunding, field bunding, land leveling have been found quite effective in conserving moisture that helped in the agricultural activities.

The following benefits were derived by the farming community in the region.

- Arrest of sea water ingress mainly resulting from the reclamation bunds which also augmented fresh water availability;
- Stored surface water brought additional area under cultivation with less salt tolerant and highly remunerative crops;
- Increased agricultural activities resulting in increased on-farm employment;
- Water conservation and harvesting devices helped in fresh water storage, and its prolonged used in post-kharif season;
- Prolonged availability of water facilitated farmers to go for additional cropping, short duration vegetables which in turn generated monetary gains;
- In cotton growing area, hybrids and Bt cotton lines got additional irrigation resulting in better yields, which otherwise used to wither away due to water shortage at critical periods of crop growth;
- *In situ* soil conservation strategies like field bunding, contour bunding, land leveling/smoothening had increased agricultural potential in the coastal belt; and
- In south Gujarat, the chances for taking summer and rabi crops have been increased mainly due to conserved water which was not the case before implementation of the works.

Recommendations offered to the Implementing Agency

1. Fund allocation for maintenance of the structures need be given priority since the very efficacy of the interventions depends on existence of perfect physical structures.
2. Deployment of trained manpower to disseminate the technical know-how through effective communication means.
3. The post-implementation phase has brought out improvement in water availability in terms of quantity and quality resulting in changes in cropping pattern and introduction of new crops which further needs to be strengthened.
4. Salinity is a key issue that affects the well being of people living in the area, the live stock and the crops. Programme of this nature should be of inter-institutional nature to derive timely benefits.
5. Preference be given to resource poor farmers which would improve their living standards.
6. The overall ground water scenario (ground water table depth, quality and quantity) has substantially increased with the advent of recharge structures and thus the technology needs to be disseminated.
7. The interventions have also brought improvement in livestock population which while meeting needs of milk and milk products.
8. Periodic soil and water testing should be made mandatory.
9. Interlinking of the farm ponds need be made for easy handling of surplus of rainfall and runoff.

Other issues that need attention

- Design, shape and location of farm pond should have consideration for storage efficiency (ratio of total volume of water that can be stored to earth work ie., (1.2) wherever not adopted.
- Deepening and reshaping of pond must have leveled bottom with proper compaction to enhance overall water storage capacity.
- Provision of sluice gate in addition to the routine causeway or culvert may be encouraged in case of reclamation bund encompassing more than a km reach to regulate the flow or runoff in tidal area without affecting salinity in upstream.
- Planting of appropriate grasses like *Dichanthium annulatum* (Marvel grass, Jinjvo) on the slopes of the reclamation bund needs to be done to minimise soil erosion so as to enhance the longevity of the structure.
- One side of the reclamation bund should have higher storage for fresh water which would enable the farmers to irrigate their crops.
- Efforts should be made for introducing salt tolerant crop varieties like paddy (CSR 23, CSR 43, CSR 30), wheat (KRL 210 and KRL 19), cotton (G Cot 23, G Cot DH 7, GShv 297/07, GBav 109, GBav 120), seed spices like cumin, dill, ajwain, fruit crops like guava, sapota, ber, and forages like multi cut jowar, rajka-bajra, Dichanthium, fodder maize etc.
- Since transfer of technology to the end users is an important aspect, time-to-time on site/off-site training programmes need to be taken up to make the farmers abreast with the interventions.

Summary

Gujarat state with 1600 km long coast line has been facing the problems of sea water ingress over the years and the problems of soil and ground water salinity have increased by nearly 5 percent from the 1980 baseline figure. Availability of good quality well water has decreased by about 33 percent and the availability of saline water has gone up proportionally. Continued abstraction of ground water in the coastal areas resulted in sea water ingress. In order to arrest sea water ingress various and to improve ground water situation in the coastal areas various mitigation measures like construction of reclamation bund, check dams, farm ponds, field bunding along with agricultural activities have been taken by GSLDC in coastal districts. The efficacy of these interventions has been evaluated and its impacts on cropping, yield increase, household income and employment generation. The studies indicated that the stored surface water brought additional area under cultivation with less salt tolerant and highly remunerative crops. Water conservation and harvesting devices helped in fresh water storage, and its prolonged used in post-kharif season. Prolonged availability of water facilitated farmers to go for additional cropping, short duration vegetables which in turn generated monetary gains. These interventions helped in improving the ground water status, storage of fresh water, improving the water quality with prolonged period of water availability which ultimately leading the higher crop productivity and living standards of the people in the region.

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References

Anonymous. 2012. Coastal Salinity in Gujarat State-Impact of Control measures Implemented by Gujarat State

Land Development Corporation, Gandhinagar, Report on the /Consultancy Project (Evaluation Study), Central Soil Salinity Research Institute, Regional Research Station, Bharuch 392 012, Gujarat, p.70.

Central Soil Salinity Research Institute, Regional Research Station, Bharuch. 2012. Coastal Salinity in Gujarat State – Impact of Control Measures Implemented by Gujarat State Land Development Corporation, Gandhinagar, Report of the Consultancy Project submitted to Gujarat State Land Development Corporation, Gandhinagar, p. 89.

Gururaja Rao, G., Chinchmaltpure, Anil. R., Arora, Sanjay, Khandelwal, M.K. and Sharma, D.K. 2013. Coastal Saline Soils of Gujarat: Problems and their Management. Technical Bulletin 1/2013, CSSRI, RRS, Bharuch.

Gururaja Rao, G., Khandelwal, M.K., Chinchmalatpure, Anil R., Arora, Sanjay and Kamra, S.K. 2010. Ground water recharging : An ideal tool for harnessing rain water in Gujarat. CSSRI Technical Brochure 05/2010, Central soil Salinity Research Institute, Karnal 132 001.

Gururaja Rao, G., Nayak, A.K. and Chinchmalatpure, Anil R. 2003. *Salvadora persica:* A Life Support Species for Salt Affected Black soils. Technical Bulletin: CSSRI/ Karnal/2003/1. Central Soil Salinity Research Institute, Regional Research Station, Anand (Gujarat). p. 44.

Gururaja Rao, G., Nayak, A.K. and Chinchmalatpure, Anil R., Singh, Ravender and Tyagi, N.K. 2001a. *Resource characterization and management options for salt affected black soils of Agro-Ecological Region V of Gujarat State*. Technical Bulletin, CSSRI/ Karnal/2001/1. Central Soil Salinity Research Institute, Regional Research Station, Anand (Gujarat). p. 83.

Jadav N.B., Viradiya, M.B. and Khunt, K.A. 2010. Adoption of Salinity Management Practices by Farmers' of Coastal Area of Western Gujarat, *Indian Res. J. Ext. Edu*. **10**(1): 37-41.

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Effect of poor quality water on the chemical properties of the salt affected soils and performance of rice

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ABSTRACT

A micro-lysimeter (1.0 meter deep and 0.3 m internal diameter) experiment was conducted to study the effect of different quality irrigation water on the soil chemical properties and their influence on growth, yield and other biometric parameters of rice (variety CSR 36). Irrigation water treatments included *viz.*, normal tap water (NTW), dilute saline water (DSW, EC_{iw} 5.0 dS m^{-1} and SAR 5.0 mmol$^{1/2}$ $L^{-1/2}$); concentrated saline water (CSW, EC_{iw} 10.0 dS m^{-1}, SAR 5.0 mmol$^{1/2}$ $L^{-1/2}$) , dilute alkali water (DAW, RSC 2.5 me L^{-1}) and concentrated alkali water (CAW, RSC 10.0 me L^{-1}). Three different type of sandy loam soils *viz.*, normal (pH_2 7.5 and EC_e 1.0 dS m^{-1}), saline (pH_2 7.7 and EC_e 10.6 dS m^{-1}) and alkali (pH_2 9.15 and EC_e 2.9 dS m^{-1}) soils were used for this investigation. Saline and alkali water irrigation affected the EC, pH and exchangeable sodium percentage (ESP) of normal, saline and alkali soils. In normal soil, EC_e increased 8.5 to 12.5 times in DSW and CSW, respectively as compared to initial experimental soil whereas, it was increased 3.2 to 4.8 times, in the alkali soil. Decrease in ECe was observed in all water treatments except CSW in saline soil as compared to initial experimental soil. Increase in pH of normal and saline soil was more pronounced in case of CAW as compared to alkali soils but decrease in pH was observed in normal, saline and alkali soils on application of DSW and CSW. Significant increase in ESP (exchangeable sodium percentage) was observed in DAW and CAW particularly in alkali soils but it in case of normal and saline soil it was observed in surface samples. ESP decreased in case of DSW and CSW in alkali soil. Cations and anions build up was more pronounced in normal soil followed by alkali and saline soils as compared to exp soil. Rice yield was at par (93%) in DAW as compared to NTW in all soils, whereas, use of CAW reduced grain yield up to 50% for normal and saline soil and in case of alkali soil it is reduced to 15% for alkali soil. Yield was further reduced to 33% in DSW for normal and saline soil and 19% for alkali soil. Yield in CSW was found negligible as total loss of crop was observed in all soils.

Key words: Residual sodium carbonate, saline soil, SAR, sodic soil

Introduction

Water is an indispensable source of life for all the system and is critical component for sustainable agriculture. Quality of irrigation water plays a pivotal role in agriculture production. The maximum poor quality water is present in arid and semi-arid areas of the India as well as world. Farmers of these regions are compelled to use poor quality groundwater. In Punjab, 41% of groundwater is brackish. Out of this 54% is sodic, 22% is highly saline and remaining 24% is saline- sodic (Minhas and Bajwa, 2001). Large areas in Rajasthan, Haryana, Uttar Pradesh, Karnataka, Punjab and Gujarat are underlain with saline and high residual sodium carbonate (RSC) groundwater (Manchanda *et al.* 1989; Manchanda, 1976) and due to prolonged use of poor quality water these areas develops sodicity and salinity problems which induces change in physico-chemical properties leading to reduced crop yield (Manchanda *et al.*, 1982; Bajwa and Josan 1989; Bajwa *et al.*, 1992; Minhas and Bajwa 2001; Choudhary *et al.*, 2002). So, farmers are compelled to do the cultivation in salt affected soils with poor quality water. The ill effect is very demoralizing and leads to poor production and productivity which nourish poor economic development, poverty, poor resource generation and other associated menaces etc. The high concentration of sodium carbonate, bicarbonate and chloride are present in irrigation water which increase soil pH, electrical conductivity and exchangeable sodium percentage (ESP) (Minhas and Bajwa, 2001; Choudhary *et al.*, 2004). Soil physical properties such as soil aeration and permeability can be adversely affected by irrigation with poor quality water (Oster and Jayawardene, 1998) due to surface sealing, clay migration leading to clogging of pores (Pratt and Suarej, 1990; Grattan and Oster, 2003; Oster, 2004). Rice and wheat is the dominating cropping system of these regions and both these crops need ample amount of water for optimum growth and yield. Further these

Table 1. Composition of irrigation waters

Characteristic	Normal tap water	Saline water		Alkali water	
	NTW	DSW	CSW	DAW	CAW
Electrical conductivity (dS m^{-1})	0.7	5.0	10.0	0.8	2.0
Ion concentration (me L^{-1})					
Ca^{2+}	1.0	20.3	46.9	1.7	3.3
Mg^{2+}	4.2	10.2	23.5	0.8	1.7
Na^{+}	3.0	19.5	29.7	5.0	15.0
Cl^{-}	0.8	33.3	66.7		
$CO_3^{2-} + HCO_3^{-}$	0.0 + 6.2	-	-	5.0	15.0
SO_4^{2-}	0.5	16.7	33.3	-	-
Sodium adsorption ratio (SAR)	1.9	5.0	5.0	-	-
Residual sodium carbonate (RSC)	1.0	-	-	2.5	10.0

[SAR = $Na^+/[(Ca^{2+}+ Mg^{2+})/ 2]^{1/2}$ in $mmol^{1/2} L^{-1/2}$; RSC = $(CO_3^{2-} + HCO_3^-) - (Ca^{2+}+ Mg^{2+})$ in me L^{-1} (all ions expressed in me L^{-1}); ratio of Ca^{2+} and Mg^{2+} or Cl^- and SO_4^{2-} were maintained at 2:1; DSW: Dilute saline water; CSW: Concentrated saline water; DAW: Dilute alkali water; CAW: Concentrated alkali water]

Table 2. Physico- chemical properties of the initial experimental soils

Soil	pH_2	EC_2	EC_e	CEC	ESP	Organic C	Sand	Fine sand	Silt	Clay	$CaCO_3$
		(dS m^{-1})		cmol $_{(p+)}$ kg^{-1}	(%)						
Normal soil	7.5	0.3	1.0	15.2	4.2	0.50	39.9	21.4	24.3	14.3	0.3
Saline soil	7.7	2.8	10.6	13.2	11.2	0.35	47.5	17.7	22.4	12.4	0.5
Alkali soil	9.2	0.8	2.9	15.5	23.9	0.42	44.1	19.7	22.5	13.7	0.4

[Textural class: sandy loam; pH_2 and EC_2: pH and electrical conductivity at 1:2 soil-water suspension; EC_e: Electrical conductivity of saturation paste; ESP: Exchangeable-Na percentage]

crops perform different under normal, saline and alkali soils conditions. Further, performance, nourishments and yield of the crops influence by the quality of irrigation water. The present investigation was, therefore, conducted to study the effect of irrigation with saline and alkali water on soil properties and performance of rice.

Materials and Methods

Collected soil and its analysis

The present study was conducted in filled-in micro lysimeters (1.0 m deep and 0.3 m internal diameter) at the experimental farm of Central Soil Salinity Research Institute, Karnal located at latitude of 29º43′ N and longitude of 76º58′ E. Three different soils (Normal soil, collected from experimental farm of Central Soil Salinity Research Institute (CSSRI), Karnal; Saline soil, collected from experimental research farm Nain, Panipat and Alkali soil, collected from Saraswati farm - Kaithal) were used for this investigation. Experimental soils were sandy loam in texture with low clay content (14.3, 12.4 and 13.7%, respectively; Table 2). Soil organic C content is medium for normal soil (0.5%) and others soils were resided with lower value. The electrical conductivity (EC_2) and conductivity of saturation extract (EC_e) for saline soil (2.8 and 10.6 dSm^{-1}) which was 3.5 and 2.7 times higher than EC_2 (0.8 dSm^{-1}) and EC_e (4.0 dSm^{-1}) of non-saline soil in many soil testing laboratories of northern India (Bajwa and Swarup, 2009). Furthermore, alkali soil had pH_2 and ESP of 9.2 and 23.9% and EC_e of 2.9 dSm^{-1}. The degree of calcareousness was less than 1% for all the soils taken for investigations. In initial experimental soil, Na^+ concentration in saturation extract was almost 3-times and 20-times higher in saline soil as compared to normal and alkali soil respectively (Table 3). Further, concentration of $Ca^{2+}+Mg^{2+}$ in saturation extract was ~7.0 and 11-times higher in saline soil compared to normal and alkali soil. Concentration of $Ca^{2+}+Mg^{2+}$ was slightly lower in alkali soil than normal soil. Conversely, Na^+ concentration was 7.0 times higher in alkali soil compared to normal soil. Soluble carbonate (CO_3^{2-}) concentration was not detectable in saturation extract of normal and saline soil, though slight enrichment of CO_3^{2-} concentration (2.0 me L^{-1}) was observed in saturation extract of alkali soil. Bicarbonate (HCO_3^-) content of 8.5 and 3.0 me L^{-1} in saturation extract was recorded in alkali and saline soil. However, lowest value of bicarbonate was recorded in normal soil. An appreciable amount of others

Table 3. Ionic composition of saturation extract (me L^{-1}) of the initial experimental soils

Soils	Ca^{2+}+ Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	CO_3^{2-}	HCO_3^-
Normal soil	5.5	4.6	0.2	4.0	3.2	0	1.0
Saline soil	42.0	88.6	0.7	58.0	46.3	0	3.0
Alkali soil	3.5	31.3	0.1	10.0	9.6	2.0	8.5

Table 4. Effect of irrigation treatments on electrical conductivity of soil saturation extract (ECe) at 2-depths after 15 irrigations under varied soils

Soils	Initial	NTW	DSW	CSW	DAW	CAW	$LSD_{0.05}$
0-15 cm							
Normal soil	1.0	1.4	8.5	12.4	2.0	2.3	1.6
Saline soil	10.6	3.0	7.1	14.3	3.0	3.9	1.6
Alkali soil	2.9	2.0	9.2	13.9	2.7	3.1	1.4
15-30 cm							
Normal soil	1.0	1.1	6.6	9.6	1.9	1.9	1.0
Saline soil	10.6	4.7	7.1	13.6	2.9	4.1	1.7
Alkali soil	2.9	1.7	7.1	10.6	2.4	2.6	1.0

anion *viz.*, Cl^- and SO_4^{2-} was detected in saturation extract of salt affected soils; but values for both the anion are low for normal soil.

The experiment was conducted in a completely randomized factorial design with three replications. Soil pH_2 and EC_2 was measured in a 1:2 soil-water suspension using a glass electrode and conductivity meter, respectively (Page *et al.*, 1982). Soil EC_e was determined by measuring the electrical conductance of soil saturation paste extract with a conductivity meter (USSL, 1954). Exchangeable-Na percentage (ESP) of soils was determined by alcoholic NH_4-chloride method described by Tucker (1971). Soil organic C was determined by wet oxidation method (Walkley and Black, 1934). Soil texture was determined by International pipette method. Calcium carbonate equivalent was measured by neutralization with HCl and cation exchange capacity (CEC) by extracting the sample with sodium acetate solution of pH 8.5. Ca^{2+} and Mg^{2+} were estimated by complexometric titration involving ethylene diamine tetra-acetic acid (EDTA) developed by Schwartzenbach *et al.*, 1946. Chloride (Cl^-) was measured by argentometric titration as described by Jackson, 1973. Carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) were determined by methyl red and phenolphthalein end point titration.

Rice and water quality treatments

Rice crop (Variety CSR 36) was transplanted during *Kharif* season (June -November) in the first week of September 2013. Initially up to 3 weeks after transplanting, the best quality available irrigation water was imposed (6 cm) after disappearance of ponded water at each lysimeter. A basal dose of 75 kg N, 60 kg P_2O_5, 40 kg K_2O and 25 kg Zn ha^{-1} was applied to the rice crop. Later on, remaining 75 kg ha^{-1} was applied as top dressing. After establishment of Rice, total 15 irrigation were imposed with five different quality water *viz.,* Normal tap water (NTW), diluted saline water of EC_w 5.0 dS m^{-1}, SAR 5.0 $mmol^{1/2}$ $L^{-1/2}$ (DSW), concentrated saline water of EC_w 10 dS m^{-1}, SAR 5.0 $mmol^{1/2}$ $L^{-1/2}$ (CSW) and diluted alkali water of RSC 2.5 meL^{-1} (DAW) and concentrated alkali water of RSC 10 meL^{-1} (CAW). These quality waters were synthesized freshly every time using bicarbonate, chloride and sulphate of calcium, magnesium and sodium in the syntax water tanks. Chemical compositions of synthetic saline and alkali water are presented in Table 1.

Rice crop was harvested in the third week of October 2013 and soil sample were again collected depth-wise and analysed to exhibit the change in chemical properties during irrigation with five different quality waters in three types of soils. During the growth of the rice crop, various biometric observations like plant height, panicle length and yield were recorded.

Results and Discussion

Electrical conductivity

Normal tap water (NTW) in saline and alkali soils decline salt loads except for normal soil. In 0-15cm soil layer, electrical conductivity (EC_e) was 8.5 and 12- times higher from initial soil when 15-irrigatiion cycles were applied under dilute (DSW) and concentrated saline water (CSW) in normal soil (Table 4). The existence of cations and anions in irrigation water can lead to increases in the EC_2 (Ould Ahmed *et al.*, 2010; Choudhary *et al.* 2004). Similarly, a slight lower account of EC_e build-up (3.2 and 4.8-times) was detected upon irrigation with same saline waters for alkali soil. Conversely, effect of salts load was

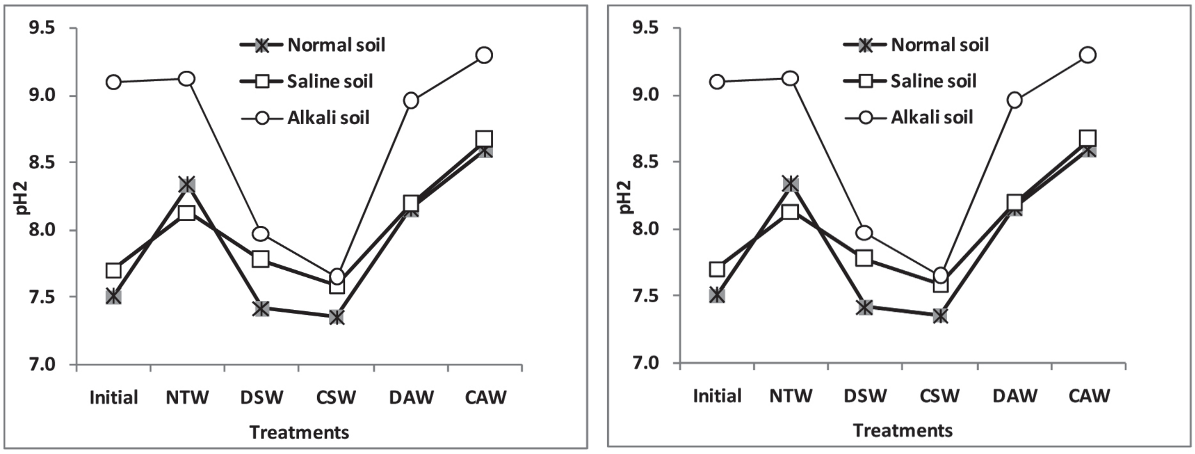


Fig. 1. Effect of irrigation treatments on soil pH (1:2 soil water ratio) at 2-depths after 15 irrigations under varied soils [$LSD_{0.05}$ 0.1, 0.2, 0.2 and 0.1, 0.2, 0.2 for 0-15 and 15-30 cm soil depth for normal, saline and alkali soil, respectively]

reduced in other water treatments whereas; it increased to ~33.0% from initial level when irrigated with concentrated saline water (CSW) in saline soil. Substantially lower EC_e values were observed in the 15–30cm layer for normal and alkali soil upon irrigation with tap and saline water. But, irrigation with same water, EC_e remained nearly same at 15-30cm layer compared to 0-15 cm in saline soil.

In 0-15cm soil layer in normal soil, electrical conductivity (EC_e) was increased to 2.0 and 2.3 dS m^{-1} from 1.0 dS m^{-1} upon irrigation with dilute and concentrated alkali water (DAW and CAW). Same alkali waters increase EC_e values nearly 2-times in the 15-30cm layer for normal soils. Substantially lower EC_e values were observed in both the soil depth when irrigated with DAW and CAW in saline soil. More or less, alkali soil remained unaffected in respect to salt load upon irrigation with alkali water. So, soil EC_e values in the normal soil, reached to the threshold level of salinity for rice (2.0 dSm^{-1}) under alkali water after 15 cycles imposed (Grattan *et al.*, 2002). Choudhary *et al.* 2011 also reported a doubling EC_e in 0-15 cm layer, under 15 year alkali water irrigation (EC_{iw} 2.1 dS m^{-1}, RSC_{iw} 12.5 meL^{-1}, SAR_{iw} 10.6 $mmol^{1/2}$ $L^{-1/2}$) in rice-wheat rotation in calcareous soil in Punjab state.

Soil pH$_2$

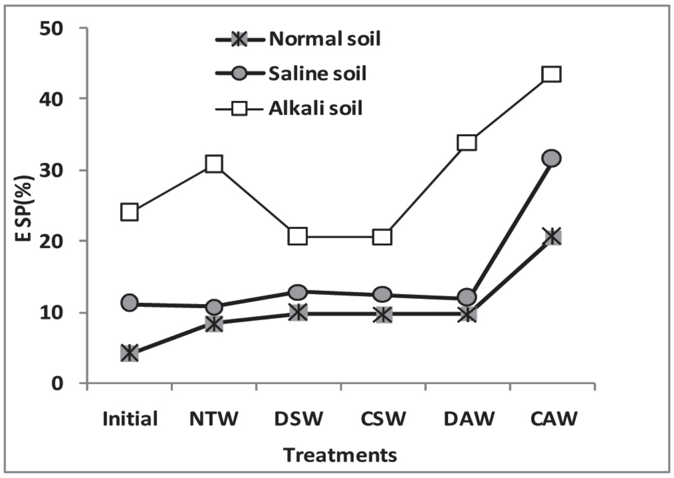
Fifteen cyclic use of tap water (NTW) irrigation increased the soil pH_2 of 0.8 and 0.3 in both the soil depth in normal and alkali soil respectively (Figure 1). The existence of cations and anions such as Na^+, HCO_3^- and Cl^- (3.0, 6.2 and 0.8 meL^{-1}) in irrigation water can lead to increases in the pH (Minhas and Bajwa, 2001; Jalali and Ranjbar, 2009). Soil pH_2 was similar to initial soil values in specific case for alkali soil when lysimeter was irrigated with NTW. The values in soil pH_2 are reasonable as soil is extremely alkali in nature and leaching of CO_3^{2-} + HCO_3^- was not happened due to low permeability (Table 6). Application of saline water DSW and CSW significantly reduced soil pH_2 for all studied soils. The range of soil pH_2 (7.4 to 7.7) was recorded as minimum compared to other water treatment for 2-respective soil depth in all soils in CSW irrigated lysimeters. However, the highest degree in decrement was 1.5 and 1.2 unit in two respective depths for alkali soil. A several time increment in ionic constituent with neutral ions [specifically Ca^{2+}, Mg^{2+} (Table 6), Cl^- and SO_4^{2-}, data not presented] through 15 cyclic water with 5.0 and 10.0 dS m^{-1} salt load might declined soil pH_2. A significant increased in pH_2 with 0.7, 0.8 units for normal soil and 0.5, 0.4 units for saline soil at respective soil depth is recorded through imposing of 15- cycle of dilute alkali water irrigation. But, changes in soil pH_2 were significantly unaffected for alkali soil at same level of irrigated condition (DAW). Around 2.2 and 1.9 units increment in soil pH_2 was speculated by Choudhary *et al.*, 2011 on a long-term (15 year) rice-wheat rotation with alkali water irrigation environment (EC_{iw} 2.1 me L^{-1}; RSC_{iw} 12.5 me L^{-1}) in normal soil (pH_2 7.9, EC_2 0.2 dS m^{-1}) in Punjab. In our experiment, a significant increment in soil pH_2 was arrived for all soils when lysimeters were fed with concentrated alkali water (RSC 10.0 me L^{-1}). Furthermore, among the 3-studied soil, the highest rise in soil pH_2 was noticed for normal soil with 1.1 unit for both soil depths followed by saline soil with 1.0 and 0.7 units for 2-respective depth and 0.25 units for alkali soil in both soil depth.

Exchangeable sodium percentage

The pictorial representation of exchangeable sodium percentage (ESP) for respective water quality irrigation at all the studied soils followed nearly similar signature for 2-soil depth (Figure 2). Graphical values revealed that ESP were highest for alkali soil (24.0-43.6, 24.0-41.2%) followed by saline soil (11.2-20.2, 11.2-20.2%) followed by normal soil (4.2-20.5, 4.2-16.8%) irrespective of imposition of any irrigation in two soil depth. ESP

Table 5. Effect of irrigation treatments on water soluble Na^+ at 2-depths after 15 irrigations under varied soils

Soils	Initial	NTW	DSW	CSW	DAW	CAW	$LSD_{0.05}$
0-15 cm							
Normal soil	4.6	7.1	47.3	55.1	13.4	17.2	3.7
Saline soil	88.6	18.4	36.5	64.5	19.2	35.0	3.0
Alkali soil	31.2	16.1	55.7	67.8	26.5	31.3	5.3
15-30 cm							
Normal soil	4.6	5.9	34.7	47.9	9.0	13.4	4.0
Saline soil	84.6	22.0	30.5	60.8	15.6	36.3	3.1
Alkali soil	31.2	14.8	50.7	63.0	23.2	22.5	2.50



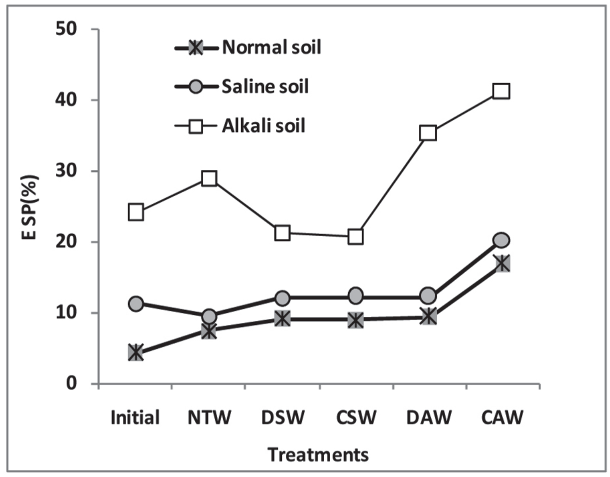


Fig. 2. Effect of irrigation treatments on exchangeable sodium percentage (ESP at 2-depths after 15 irrigations in varied soils [$LSD_{0.05}$ 2.5, 3.7, 5.3 and 1.2, 2.6, 5.0 for 0-15 and 15-30 cm soil depth for normal, saline and alkali soil, respectively]

became double upon irrigation with NTW, saline water (DSW, CSW) and dilutes alkali water (DAW) for normal soil as compared to initial experimental soil. These results indicate that a considerable increase in soil ESP occurred due to application of a saline/ sodic water to soil that did not receive any chemical/ organic amendments (Choudhary *et al.*, 2004; Jalali and Ranjbar, 2009) found similar type of increased in ESP from 10.1 to 19.8 in column-leaching experiment with calcareous sandy loam soil (pH_2 7.5, EC_2 2.3 dS m^{-1}). But, ESP of saline soil remained nearly unaffected when treated with other quality waters except concentrated alkali water. Upon irrigation with alkali water with RSC 10.0 me L^{-1} increased ESP around 4.9, 4.0 times for normal and 2.8, 1.8 times for saline and alkali soil in two depth respectively. The rate of increase was more due to prior to establishment of quasi-equilibrium. The soil salinity-sodicity is usually depend on nature of salts and its load, soil characteristics, nature of crops grown and rainfall frequency and evaporation demands. So, sodicity built-up (< 15% ESP) is not attained as residual alkalinity (RSC) of the quality water was ≤ 2.5 me L^{-1} for NTW and DAW; and RSC was nil for saline water. Therefore, RSC of 2.5 me L^{-1} is prescribed by most of water testing laboratory for safe use of water as irrigation without its deleterious effects. (Bajwa and Swarup, 2009). Additionally, it was visualized that irrigation with moderate SAR (5.0 $mmol^{1/2} L^{-1/2}$) with saline waters have not any adverse effects like sodification. But long-term use of saline water with moderate SAR (~6) leads to caused high ESP (US Salinity Laboratory Staff 1954). Irrigation water with high residual alkali water had a priming effect to build-up sodicity in alkali soil. It is revealed with the end ESP values of >40.0 in alkali soil along two soil depth from its initial level 23.9. Several reports on the sodicity build up in soils due to short/ prolong irrigation with waters having residual alkalinity have come up from north-west parts of the country in both soils.(Choudhary *et al.*, 2006; Minhas *et al.*, 2007; Choudhary *et al.*, 2011).

Ion analysis

The wash out of soluble cation (Na^+, Ca^{2+} and Mg^{2+}) and alkali ions (CO_3^{2-} and HCO_3^-) was expected under NTW treatment for all soils (Table 4, 5 and 6). A preferential Na^+ holding in soil was noticed upon irrigation with both dilute and concentrated saline water. Substantial amount of Na^+ in irrigation water (EC_{iw} 5.0 and 10.0 dS m^{-1}; SAR 5.0 $mmol^{1/2} L^{-1/2}$) can increase Na^+ in soil. A go-between account of Na^+ holding was resided

Table 6. Effect of irrigation treatments on water soluble ions at 2-depths after 15 irrigations under varied soils

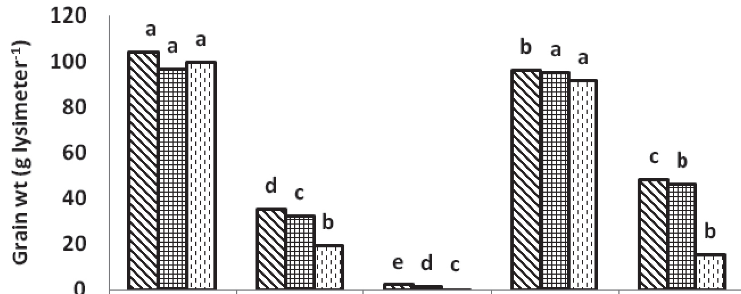
Soils	Initial	NTW	DSW	CSW	DAW	CAW
			Ca^{2+}+ Mg^{2+}			
0-15 cm						
Normal soil	5.5	5.0	58.5	91.2	14.6	9.6
Saline soil	42.0	30.9	52.2	98.3	23.0	19.2
Alkali soil	3.6	5.3	35.4	92.8	6.4	5.3
15-30 cm						
Normal soil	5.5	4.2	39.1	79.5	8.7	7.1
Saline soil	42.0	36.5	49.4	90.1	25.4	31.8
Alkali soil	3.6	4.7	21.1	52.3	4.7	4.0
			CO_3^{2-} + HCO_3^-			
0-15 cm						
Normal soil	1.0	0.9	1.1	2.0	1.5	2.0
Saline soil	3.0	2.8	2.5	2.5	2.0	3.0
Alkali soil	10.0	8.0	2.5	2.5	7.5	10.5
15-30 cm						
Normal soil	1.0	0.9	1.1	2.0	2.0	1.5
Saline soil	3.0	2.8	3.0	2.0	2.0	3.0
Alkali soil	10.0	8.5	3.0	3.5	8.5	10.0

in both salt affected soils when fed with alkali water. The occurrence of Na^+ is higher when irrigation with CAW compared to DAW. Inherent Na^+ in soil solution for saline soil viewed more Na^+ for saline soil; continuous irrigation with alkali water (Na^+ 5.0 and 15.0 me L^{-1}) can increased the holding of Na^+ in alkali soil. An appreciable amount of Na^+ in soil solution was reported by Basak *et al.*, 2014 when salts affected soils (saline- alkali and alkali) were fed with saline water (EC_{iw} 6.0 and 12. dS m^{-1}; SAR 5.0 mmol$^{1/2}$ $L^{-1/2}$) in column-leaching experiment. Furthermore, continuous use of alkali waters caused poor soil permeability and reduced leaching of Na^+ (Choudhury *et al.*, 2004).

Irrigation with NTW resulted in significant decrease in divalent cations (Ca^{2+}+ Mg^{2+}) content specifically for saline soil; all level of Ca^{2+}+ Mg^{2+} content was unaffected for normal and alkali soil when compared with initial soil. An around ~10 and 20 fold increase in Ca^{2+}+ Mg^{2+} content was recorded upon irrigation with DSW and CSW for both normal and alkali soil in 2-soil depth. Whereas, 1.2 and 2-times increment in Ca^{2+}+ Mg^{2+} load is reported for saline soil. Only enrichment of CO_3^{2-} + HCO_3^- ions is reported in alkali soil when fed with concentrated alkali water. Poor permeability, decrease in infiltration was significant impact on CO_3^{2-} + HCO_3^- loading in alkali soil when fed with water having residual alkalinity (Minhas *et al.*, 2007).

Crop yield

Continuous saline and alkali irrigation significantly affected the yield contributing parameters of rice, including plant height, panicle length and grain weight (Figure 3, Table 7, $P>$ 0.01). These adverse effects were relatively severe in case of saline water irrigation compared to alkali water. Nearly total loss in crop emergence was recorded for all soil when irrigated with CSW water. Around 70% less grain yield for normal and saline soil and 80% less for alkali soil harvested when irrigation was imposed with dilute saline water (DSW, EC_{iw} 5.0 dS m^{-1}). Only 7% yield penalty was observed with irrigation with DAW in normal soil as compared to NTW; but saline and sodic soils were unaffected. Sustain use of CAW reduced grain yield up to 50% for both normal and saline soils. Only 15% grain compared to NTW was collected upon irrigation with concentrated alkali water for alkali soil. None of plant mortality was reported when irrigation was fed with alkali water. An increase in soil pH and ESP due to irrigation with alkali water caused a significant reduction in crop yields for all type of soils (Minhas *et al.*, 2007). In specific case for alkali soil the reported ESP build up is 41.0 which is close to ESP 60 for 50% yield decline in rice as coined by Choudhary *et al.*, 2011 for threshold yield value. Furthermore, inherent alkalinity of soil (CO_3^{2-} + HCO_3^- 10.5 me L^{-1}; ESP 24) transformed to more deleterious to rice upon addition of irrigation with 10.0 me L^{-1} residual alkali water in alkali soil (CO_3^{2-} $P>$ 0.05; HCO_3^- > 0.01, Table 7). Minhas and Sharma (2004) found more prone to alkali effects for rice under alkali water irrigation in original alkali soil. But, direct salinity stress for rice is only appeared with concentrated saline water irrigation for all soil with nearly total failure of seedlings stand. The salinity stress in the rooting zone of paddy is reported



	NTW	DSW	CSW	DAW	CAW
Normal soil	103.6	35.2	1.8	95.9	48.1
Saline soil	96.3	31.9	1.1	94.9	46.0
Alkali soil	99.4	19.0	0.5	91.4	15.1

Fig. 3. Effect of irrigation water treatments on grain yield under varied soils [Numbers followed by different lowercase letters are significantly different between C pools at *P* d” 0.05 by Duncan’s multiple-range test]

Table 7. Correlation coefficient (r) relating soil properties / plant biometric observations are the independent variables and the grain yield as dependent variables

Soil properties plant biometric observations	Normal soil		Saline soil		Alkali soil	
	0-15	15-30	0-15	15-30	0-15	15-30
ECe	-0.856**	-0.872**	-0.875**	-0.871**	-0.749**	-0.728**
pH	0.666**	0.668**	0.525*	0.386	0.604*	0.673**
ESP	-0.168	-0.202	-0.127	-0.203	0.255	0.289
Na^+	-0.904**	-0.916**	-0.948**	-0.903**	-0.813**	-0.748**
Ca^{2+}	-0.857**	-0.858**	-0.797**	-0.785**	-0.637*	-0.632*
Mg^{2+}	-0.849**	-0.861**	-0.780**	-0.789**	-0.650**	-0.662**
CO_3^{2-}	.a	.a	.a	.a	0.529*	0.521*
HCO_3^-	-0.154	-0.13	0.147	0.121	0.454	0.709**
Cl^-	-0.867**	-0.880**	-0.868**	-0.869**	-0.729**	-0.734**
SO_4^{2-}	-0.791**	-0.840**	-0.700**	-0.749**	-0.731**	-0.714**
Plant height	0.822**	0.822**	0.930**	0.930**	0.756**	0.756**
Panicle length	0.878**	0.878**	0.837**	0.837**	0.766**	0.766**

[** and * are Correlation is significant at the 0.01 and 0.005 level (2-tailed); a. cannot be computed]

only 1.8 dS m^{-1} (Minhas and Gupta, 1992). Naturally, extremely salinity can appear as total crop mortality *vis-à-vis* moderate salinity reduced 70-80% yield penalty.

Conclusions

It can be concluded that on application of poor quality water salinity and alkalinity was more pronounced in normal soil followed by alkali and saline soils which leads to more risk of normal soil degradation as compared to saline and alkali soils. Continuous irrigation with concentrated saline water increases EC_e of root zone soil and its deleterious effect on crop followed by complete crop mortality. Alkali water irrigation remarkably increment the soil pH and ESP of all soils under consideration. Grain mortality was found maximum in CSW followed by DSW and CAW but has little effect on DAW as compared to NTW. Grain yield in saline and alkali soils were unaffected in NTW and DAW. Increase in salinity can impact yield as rice is more sensitive to salinity than alkalinity.

References

Bajwa, M.S., Choudhary, O.P. and Josan, A.S. 1992. Effect of continous irrigation with sodic and saline-sodic waters on soil properties and crop yields under cotton-wheat in north-western India. *Journal of Indian Society of Soil Science*, IARI, New Delhi, 329-339.

Bajwa, M.S. and Josan, A.S. 1989. Effect of alternating sodic and non-sodic irrigations on the build up of sodium in the soil and crop yields in northern India, *Exp.Agric.* **25**: 199-205.

Bajwa, M.S. and Swarup, A. 2009. Soil salinity and alkalinity. In: *Fundamentals of Soil Science*. Indian Society of Soil Science, IARI, New Delhi, 329-339.

Basak, N., Chaudhari, S.K. and Sharma, D.K. 2014. Impact of varying Ca:Mg waters on ionic balance, dispersion and clay flocculation of salt affected soils. *Communication in Soil Science & Plant Analysis.*

Choudhary, O.P., Ghuman, B.S., Bijay-Singh, Thuy, N. and Buresh, R.J. 2011. Effect of long-term use of sodic water irrigation, amendment and crop residues on soil properties and crop yields in rice-wheat cropping system in a calcarious soil. *Field Crop Res.* **121**: 363-372.

Choudhary, O.P., Ghuman, B.S., Josan, A.S. and Bajwa, M.S. 2006. Effect of alternating irrigation with sodic and non-sodic waters on soil properties and sunflower yield. *Agriculture Water Management* **85**: 151-156.

Choudhary, O.P., Josan, A.S., Bajwa, M.S. and Kapur, M.L. 2004. Effect of sustained sodic and saline sodic irrigation and application of gypsum and farmyard manure on yield and quality of sugarcane under semi-arid conditions. *Field Crops Res.* **87**: 103-116.

Choudhary, O.P., Josan, A.S. and Bajwa, M.S. 2002. Role of organic materials in mobilizing intrinsic calcium carbonate to ameliorate sodic irrigations. In: Procedings of the 17th World Congress on Soil Science, Symposium no. 34, Abstracts Vol., III, *Symposia 22- 36*, 1162.

Grattan, S.R., Michael, L.Z., Shannon, M.C. and Roberts, S.R. 2002. Rice is more sensitive to salinity than previously thought. *Calif. Agric.* **56**: 189-195.

Grattan, S.R. and Oster, J.D. 2003. Use and re-use of saline-sodic waters for irrigation of crops. *J. Crop Prod*. **7**: 131-162.

Gupta, R.K., Singh, C.P. and Abrol, I.P. 1985. Determoning cation exchange capacity and exchangeable sodium in alkali soils. *Soil Sci.* **139**: 326-331.

Jackson, M.L. (1973). *Soil Chemical Analysis*. Prentice Hall India Pvt. Ltd., New Delhi.

Jalali, M., and Ranjbar, F. 2009. Effects of sodic water on soil sodicity and nutrient leaching in poultry and sheep manure amended soils. *Geoderma,* **153**: 194-204.

Manchanda, H.R. 1976. Quality of Ground Waters of Haryana HAU, Hisar.

Manchanda, H.R., Gupta, I.C. and Jain, B.L. 1989. Use of poor quality waters. (In) *Reviews of Research on Sandy Soils of India*, February 6-10, 1989, 362-383. International Symposium on Managing Sandy Soils of India, CAZRI, held at Jodhpur.

Manchanda, H.R., Verma, S.L. and Khanna, S.S. 1982. Identificaion of some factors for use of sodic waters with high residual sodium carbonate. *Journal of Indian Society of Soil Science* **30**: 353-360.

Minhas, P.S. and Bajwa, M.S. 2001. Use and management of poor quality waters for the rice-wheat based production system. *Journal Crop Production* **4**: 273-305.

Minhas, P.S., Dubey, S.K. and Sharma, D.R. 2007. Comparative affects of blending, intera / inter-seasonal cyclic uses of alkali and good quality waters on soil properties and yield of paddy and wheat. *Agricultural Water Management* **87**: 83-90.

Minhas, P.S. and Gupta, R.K. 1992. Quality of Irrigation Water Assessment and Management. ICAR Publications, New Delhi, 123.

Minhas, P.S. and Sharma, O.P. 2004. A re-look at the diagnostic criteria for salt-affected soils in India. In: Proceedings of the International Conference on ''Sustainable Management of Sodic Soils'', UPCAR, Lucknow.

Oster, J.D. 2004. Amendment use to mitigate the adverse effects of sodic water. In: Proceedings of the International Conference on Sustained management of sodic lands, Extended Summaries, UPCAR, Lucknow, India, 89-91.

Oster, J.D. and Jaywardene, N.S. 1998. Agricultural management of sodic soils. In: Summer, M.E., Naidu, R. (Eds), Sodic soils: Distribution, Processes, Management and Environmental Consequences. Oxford University Press, 125-147.

Ould Ahmed, B.A., Inoue, M. and Moritani, S. 2010. Effect of saline water irrigation and manure application on the available water content, soil salinity, and growth of wheat. *Agricultural Water Management* **97**: 165-170.

Page, A.L., Miller, R.H. and Keeney, D.R. (eds.). 1982. Methods of Soil Analysis, Part-2, Second Edition, *Soil Science Society America Journal,* Madison, Wisconsin, USA.

Pratt, P.F. and Suarej, D.L. 1990. Irrigation water quality assessment. In: Tanji, K.K. (Ed.) *Agricultural Salinity Assessment and Management*, **71**. ASCE manual, 220-236.

Schwartzenbach, G., Biedermann, W. and Bangerter, F. 1946. Komplexone VI. Meue einfache Titrimethoden zur Bestimmung der Wesserharte. *Helvetica Chimica Acta*. **29**: 811-818.

Tucker, B.M. 1971. The partitioning of exchangeable magnesium, calcium and sodium in relation to their effects on the dispersion of Australian clay subsoils. *Australian Journal Soil Research* **23**: 405-416.

Richards, L.A. 1954. *Diagnosis and Improvement of Saline and Alkali Soils*. USDA Handbook **60**, Washington, DC.

Walkley, A.J., and Black, I.A. 1934. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science* **37**: 29-38.

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Irrigation water quality impact on moisture retention characteristics of different soils of Northern Ghana

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ABSTRACT

A study was carried out to quantify the effect of SAR and TEC of equilibrating solution on water retention characteristics and water constants of clay, clay loam and silt loam soils of Northern Province of Ghana. Soil samples were equilibrated with twenty four water quality combinations comprising six levels of sodium adsorption ratio (SAR) *viz;* 2.5, 5, 10, 15, 20 and 30 m mol$^{1/2}$ L$^{-1/2}$ and four levels of total electrolyte concentration (TEC) *viz;* 5, 10, 20 and 50 meL^{-1} synthesised using chloride salts of calcium, magnesium and sodium at Ca : Mg = 2:1. Water retention by these soil samples was evaluated at suctions of 0 - 1500 kPa. Water constants were studied as drainable water (DW), available water (AW) and residual water (RW). Near saturation, in the range of 0 to 5 kPa negligible effect of water quality on water retention was noticed. At an equilibrium suction of 10 kPa, effect of water quality was observed only when SAR was above 15 m mol$^{1/2}$ L$^{-1/2}$ in clay and clay loam and at SAR 30 m mol$^{1/2}$ L$^{-1/2}$ in silt loam soil. In the range of 20 to 1000 kPa water retention increased sharply with increase in SAR and decrease in TEC, thereafter increase was slow upto 1500 kPa. A spectacular rise in AW was recorded with increase in SAR and decrease in TEC. Such increase in AW was associated with sharp decline in DW, however influence of water quality on RW was marginal. SAR of the equilibrating solution was found to be highly effective parameter as compare to TEC. Increase in AW and decrease in DW were positively related with the water quality induced changes in dispersion and ESP of the soil. However, the water quality induced changes in soil dispersion marginally affected the RW.

Key words: available water, dispersion, drainable water, residual water, water retention

Introduction

Ghana's agriculture goes as far back as the 10th century when the first settlers from the old Mali Empire made entry (Stride and Ifeke, 1971) and now accounts for 33% of GDP (CIA World Fact book, 2011). Ghana with a total area of 23.8 million ha has only 13.6 million ha of arable land which is mostly rainfed (Adiku *et al.*, 1997) of which only 5.3 million ha is cultivated to produce sufficient food even at an annual population growth rate of 2.6% (FAO, 2000). With a growth in GDP of 5.2% in 2004 to 11.9% in 2008, agriculture's contribution to GDP is also expected to grow with it. Increased agriculture contribution cannot be realized without a conscious effort to grow crops year round. Year round agricultural production is only achievable through increased irrigation. Nonetheless, irrigation is normally the major cause of salinization of soils (Rietz and Haynes, 2003). Also the irrigation water quality in most part is poor. The more irrigation extends the more salinity of soils significantly alters (González-Núñez *et al.*, 2004 and Siadat, 1998). Therefore, it does not come as a surprise that from 1989 (Choukr-Allah, 2004) to 2000, there has been an increase in the expanse of Ghanaian saline soils from 318,000 ha to 790,000 ha. This indicates that the techniques that Ghana is using for managing its saline soils are not very effective. Thus, the there is a need to review the technique(s) that Ghana is using widely to manage its saline soils.

Irrigation is an important force in agricultural development. The sustainability of irrigated agriculture, however, now faces a growing risk of salinization and waterlogging. In arid and semi-arid regions of Ghana, ground water is either the major or the only source of irrigation to supplement the scanty rainfall and is sometimes charged with excessive soluble salts. Continuous usage, fully or partly of such poor quality waters deteriorate the physical and chemical properties of soils and ultimately productivity. The nature and concentration of cationic species influence water retention characteristics and different water constants in the soils.

Table 1. Physical and chemical characteristics of soils

Soil Type	Sand	Silt	Clay	pH	EC	$CaCO_3$	Org. C.	CEC	ESP
	%				dSm^{-1}	%	$g\ kg^{-1}$	$c\ mol\ (p^+)\ kg^{-1}$	%
Clay	23.5	21.2	55.3	7.98	0.68	2.75	6.4	55.2	1.92
Clay loam	40.5	23.8	35.7	8.19	0.54	3.32	4.2	36.5	1.52
Silt loam	42.6	34.0	23.4	7.87	0.79	0.96	3.2	18.3	0.59

Reitemeir (1946) was the first to demonstrate the effect of soluble and exchangeable ions on soil-water content in arid region soils. Acharya and Abrol (1978) studied the water retention characteristics of sodic soils. Sandhu *et al.* (1980) observed uniform water retention upto 100 kPa suction at different ESP in saline and sodic soils. Malik *et al.* (1992) studied the water quality effect on water retention characteristics and found that at a given suction water retention increases with increase in SAR and decrease in TEC of the saturating solution. Most of such studies were confined to the Illite dominated alluvial soils, however information is meagre on the different soils of Ghana. In view of this, an attempt was made to study the effects of irrigation water quality on water retention characteristics and water constants of major irrigated soils of Northern Ghana.

Materials and methods

The bulk soil samples were collected from upper 30 cm depth of A or Ap horizon of clay, clay loam and silt loam soils from the farmers fields in various places in Northern Ghana. The basic physico-chemical properties of these soils are presented in Table 1.

Twenty four qualities of water were synthesised comprising six levels of sodium adsorption ratio (SAR) viz. 2.5, 5, 10, 15, 20 and 30 $m\ mol^{1/2}\ L^{-1/2}$ and four levels of total electrolyte concentration (TEC) viz., 5, 10, 20 and 50 meL^{-1}. To avoid the supplementary effect of magnesium on ESP Ca : Mg was kept at 2:1. Pure A.R. grade chloride salts of calcium, magnesium and sodium were used to synthesise different quality waters.

Buchner funnels with internal diameter 15 cm and height 7.5 cm were used to equilibrate soil samples. The desired quality of water was allowed to pass through the soil placed in buchner funnel. The process of equilibration thought to be completed when draining solution attained the same EC that of equilibrating solution. In some cases, when drainage was completely ceased due to high SAR waters, uniform suction of 0.5 kPa using a vacuum pump was applied to facilitate the equilibration.

Equilibrated soil samples packed at bulk density of 1.3, 1.35 and 1.45 $Mg\ m^{-3}$ were used to study the water retention characteristics of clay, clay loam and silt loam soils respectively. At saturation water retention determined by using saturation cans. The soil filled cans were allowed to saturate over-night in the given quality water by capillarity. Excess water was allowed to drain on a dry filter paper. Moist weight of saturated soil filled cans were recorded. For drying, cans were transferred in a oven at 105°C.

Water retention in the low suction range of 1 to 5 kPa was determined by using a sand box apparatus. The equilibrated soil samples were packed in the metallic cores at the desired bulk density and allowed to saturate over-night in the given water quality. The saturated soil filled cores were transferred to the sand bed of the apparatus. The magnetic indicator of the apparatus was set to the height equivalent to 10.23 and 51.15 cm of water column for equivalent suction of 1 and 5 kPa. When outflow stopped completely, soil samples were thought to be equilibrated at given suction

Water retention at and above 10 kPa suction was determined by a pressure plate apparatus as described by Bruce and Luxmoore (1986). Equilibrated soil samples filled in water retention rings on desired bulk density were placed on ceramic plates. Ceramic plates alongwith water retention rings were allowed to saturate over-night in the same quality water. After proper assembling of the apparatus, desired air pressure each of 10, 20, 33, 50, 70,

Table 2. Number of absolute pore volumes and time needed to equilibrate the soil samples

TEC ($me\ L^{-1}$)	SAR ($m\ mol^{1/2}\ L^{-1/2}$) 2.5	5	10	15	20	30
	Nos'					
Clay						
5	14	15	16	19	20	22
10	13	14	15	16	19	21
20	12	13	14	15	17	19
50	11	15	16	14	15	18
Clay loam						
5	12	13	14	18	19	20
10	11	13	13	14	18	20
20	11	12	13	14	16	18
50	10	13	15	14	14	17
Silt loam						
5	7	8	10	9	10	11
10	7	8	5	6	8	10
20	6	7	7	6	7	9
50	5	5	5	6	6	8

Table 3. Effect of water qualities on water retention characteristics of clay soil (SAR in m mol$^{1/2}$L$^{-1/2}$ and TEC in me L^{-1})

TEC	Equilibrium suction kPa														ESP
	0	1	5	10	20	33	50	70	100	300	500	700	1000	1500	
	cm^{3}cm^3														
							SAR 2.5								
5	0.69	0.67	0.61	0.46	0.42	0.40	0.38	0.36	0.32	0.32	0.26	0.23	0.22	0.20	3.94
10	0.70	0.66	0.60	0.54	0.48	0.46	0.42	0.41	0.40	0.32	0.26	0.24	0.19	0.18	3.94
20	0.70	0.65	0.61	0.44	0.42	0.40	0.38	0.36	0.31	0.22	0.21	0.19	0.17	0.17	4.19
50	0.70	0.65	0.62	0.41	0.41	0.37	0.36	0.34	0.30	0.28	0.28	0.25	0.25	0.24	4.25
							SAR 5								
5	0.71	0.66	0.62	0.40	0.39	0.38	0.38	0.36	0.34	0.33	0.32	0.28	0.24	0.18	5.21
10	0.70	0.67	0.61	0.44	0.42	0.36	0.36	0.36	0.34	0.34	0.31	0.25	0.22	0.18	5.57
20	0.69	0.65	0.60	0.50	0.43	0.40	0.37	0.35	0.35	0.34	0.30	0.25	0.22	0.17	6.28
50	0.69	0.65	0.61	0.43	0.42	0.40	0.37	0.35	0.34	0.32	0.29	0.24	0.20	0.17	5.21
							SAR 10								
5	0.71	0.67	0.62	0.42	0.42	0.41	0.41	0.38	0.38	0.37	0.35	0.29	0.23	0.19	5.75
10	0.71	0.66	0.61	0.41	0.41	0.40	0.40	0.37	0.37	0.36	0.34	0.28	0.22	0.19	7.23
20	0.69	0.67	0.62	0.40	0.40	0.40	0.37	0.36	0.36	0.36	0.32	0.26	0.22	0.18	11.35
50	0.70	0.65	0.60	0.43	0.43	0.38	0.36	0.35	0.35	0.35	0.31	0.25	0.20	0.18	9.50
							SAR 15								
5	0.70	0.67	0.62	0.52	0.52	0.46	0.43	0.40	0.38	0.37	0.36	0.31	0.24	0.20	7.06
10	0.70	0.67	0.61	0.50	0.50	0.44	0.42	0.37	0.37	0.36	0.35	0.30	0.23	0.19	8.00
20	0.70	0.65	0.60	0.49	0.49	0.43	0.41	0.36	0.36	0.35	0.35	0.29	0.22	0.19	14.60
50	0.69	0.66	0.60	0.48	0.48	0.42	0.40	0.35	0.35	0.35	0.34	0.28	0.20	0.18	14.67
							SAR 20								
5	0.68	0.65	0.60	0.59	0.54	0.49	0.46	0.42	0.42	0.40	0.38	0.35	0.24	0.22	7.32
10	0.69	0.66	0.61	0.58	0.53	0.48	0.44	0.41	0.41	0.38	0.37	0.34	0.23	0.20	8.76
20	0.69	0.67	0.62	0 .58	0.52	0.47	0.43	0.41	0.40	0.37	0.36	0.32	0.23	0.19	16.32
50	0.70	0.66	0.61	0.56	0.50	0.46	0.42	0.40	0.37	0.36	0.35	0.31	0.22	0.18	17.35
							SAR 30								
5	0.71	0.67	0.62	0.62	0.58	0.54	0.49	0.46	0.42	0.42	0.40	0.36	0.25	0.24	8.67
10	0.68	0.66	0.61	0.60	0.56	0.53	0.48	0.44	0.41	0.41	0.38	0.35	0.24	0.23	11.03
20	0.69	0.66	0.60	0.59	0.56	0.52	0.47	0.43	0.38	0.37	0.37	0.34	0.23	0.22	19.87
50	0.70	0.67	0.61	0.58	0.55	0.50	0.47	0.42	0.37	0.36	0.36	0.32	0.22	0.20	20.57
Normal soil	0.70	0.66	0.62	0.40	0.36	0.34	0.33	0.32	0.29	0.25	0.22	0.19	0.19	0.18	1.92

100, 300, 500, 700, 1000 and 1500 kPa adjusted separately for each sample in the order by operating the pressure value. The pressure valve was closed when the outflow was completely ceased and the apparatus was disassembled. Moist and dry weights of soil samples were recorded.

Water retention was computed from the difference between moist and dry weights. All determinations were carried out in triplicate. Water contents recorded gravimetrically in different suction ranges were multiplied by respective bulk density to get volumetric water contents. From complete suction - water content relationship different water constants viz., drainable, available and residual water were computed as :

Drainable water = Water drained between 0 and 33 kPa
Available water = Water drained between 33 and 1500 kPa
Residual water = Water retained at 1500 kPa

In order to quantify the effect of water quality on different water constants, a linear regression analysis was carried out between different water constants and exchangeable sodium per cent (ESP) or dispersion index (DI) of the soils. ESP of the soils was determined by alcoholic ammonium chloride method as described by Tucker (1971). DI as defined by Mustafa and Letey (1969)

Table 4 . Effect of water qualities on water retention characteristics of clay loam soil (SAR in m mol$^{1/2}$L$^{-1/2}$ and TEC in me L^{-1})

TEC	Equilibrium suction kPa														ESP
	0	1	5	10	20	33	50	70	100	300	500	700	1000	1500	
	cm^{3}cm^3														
							SAR 2.5								
5	0.60	0.55	0.51	0.37	0.33	0.33	0.33	0.30	0.25	0.28	0.19	0.19	0.18	0.17	3.94
10	0.59	0.54	0.49	0.44	0.39	0.38	0.38	0.37	0.33	0.29	0.24	0.18	0.16	0.15	4.40
20	0.59	0.53	0.51	0.49	0.47	0.44	0.42	0.40	0.32	0.30	0.26	0.17	0.16	0.15	4.41
50	0.58	0.54	0.49	0.47	0.46	0.34	0.34	0.34	0.32	0.32	0.32	0.30	0.26	0.17	5.28
							SAR 5								
5	0.59	0.53	0.51	0.37	0.36	0.36	0.35	0.34	0.34	0.34	0.33	0.33	0.29	0.19	5.48
10	0.58	0.53	0.51	0.34	0.36	0.36	0.35	0.34	0.34	0.29	0.28	0.21	0.18	0.16	6.72
20	0.58	0.54	0.50	0.32	0.32	0.31	0.31	0.28	0.26	0.26	0.26	0.19	0.18	0.16	7.75
50	0.59	0.55	0.49	0.40	0.40	0.36	0.30	0.29	0.28	0.26	0.25	0.18	0.17	0.15	6.45
							SAR 10								
5	0.60	0.55	0.50	0.39	0.38	0.37	0.34	0.32	0.32	0.32	0.31	0.29	0.19	0.17	7.92
10	0.59	0.54	0.49	0.37	0.37	0.34	0.34	0.31	0.31	0.31	0.31	0.24	0.18	0.17	10.23
20	0.59	0.54	0.48	0.36	0.36	0.33	0.33	0.32	0.30	0.29	0.28	0.23	0.19	0.16	12.96
50	0.58	0.53	0.49	0.41	0.36	0.33	0.32	0.29	0.29	0.28	0.26	0.22	0.18	0.15	11.89
							SAR 15								
5	0.59	0.55	0.50	0.47	0.46	0.41	0.37	0.33	0.32	0.32	0.31	0.28	0.22	0.17	7.66
10	0.59	0.54	0.50	0.46	0.46	0.41	0.36	0.32	0.31	0.32	0.30	0.26	0.21	0.17	10.39
20	0.59	0.54	0.49	0.45	0.45	0.39	0.34	0.31	0.30	0.31	0.29	0.25	0.19	0.16	17.15
50	0.58	0.53	0.48	0.44	0.44	0.38	0.33	0.30	0.29	0.30	0.28	0.24	0.18	0.16	17.01
							SAR 20								
5	0.60	0.54	0.49	0.53	0.49	0.45	0.39	0.36	0.36	0.33	0.33	0.29	0.23	0.18	8.84
10	0.59	0.55	0.50	0.52	0.48	0.44	0.38	0.36	0.34	0.32	0.32	0.28	0.23	0.17	11.74
20	0.58	0.53	0.51	0.51	0.48	0.42	0.33	0.33	0.34	0.31	0.31	0.26	0.21	0.16	21.07
50	0.59	0.53	0.50	0.49	0.47	0.41	0.36	0.32	0.33	0.30	0.30	0.25	0.19	0.16	12.01
							SAR 30								
5	0.60	0.55	0.51	0.54	0.52	0.46	0.42	0.37	0.34	0.33	0.31	0.26	0.23	0.21	10.95
10	0.60	0.54	0.50	0.52	0.51	0.45	0.41	0.36	0.34	0.32	0.31	0.26	0.22	0.19	16.11
20	0.59	0.53	0.50	0.52	0.49	0.44	0.40	0.34	0.31	0.31	0.30	0.25	0.21	0.18	24.75
50	0.60	0.54	0.49	0.51	0.48	0.42	0.38	0.33	0.28	0.30	0.28	0.24	0.19	0.17	25.15
Normal soil	0.59	0.54	0.50	0.34	0.32	0.32	0.32	0.30	0.25	0.23	0.21	0.18	0.17	0.17	1.52

was calculated as DI = [Water dispersible (silt + clay)/ Total (silt + clay)] x 100.

Results and discussion

The data presented in Table 3 through 5 revealed that at any equilibrium suction, water retention was in the order clay > clay loam > silt loam. In general, water retention was high when water quality was characterised by low TEC and high SAR. Effect of water quality on saturation water content in different soils was least and per cent variation ranged between -2.86 and 1.43, 1.7 and -1.7 and -2.2 and 6.7 in clay, clay loam and silt loam soils respectively. In extremely low suction range (0 to 5 kPa) negligible reduction in water retention with no definite trend was observed in clay and clay loam soils. However, reduction in water retention by silt loam soil was noticed. Such reduction increased with progressive increase in SAR. Effect of TEC was not obvious in extremely low suction range. At an equilibrium suction of 10 kPa effect of water quality was noticed above SAR 15 m mol$^{1/2}$ L$^{-1/2}$ in clay and clay loam soils wherein water retention increased by 20 and 29.4 per cent at SAR 15 m mol$^{1/2}$ L$^{-1/2}$, TEC 30 me L^{-1} and 55 and 58.5 per cent at SAR 30 m mol$^{1/2}$ L$^{-1/2}$, TEC 5 me L^{-1} over normal clay and clay loam soils, respectively. However, in silt loam soil increase

Table 5. Effect of water qualities on water retention characteristics of silt loam soil (SAR in m $mol^{1/2}L^{-1/2}$ and TEC in me L^{-1})

TEC	Equilibrium suction kPa														ESP
	0	1	5	10	20	33	50	70	100	300	500	700	1000	1500	
	cm^3cm^3														
							SAR 2.5								
5	0.45	0.40	0.37	0.36	0.32	0.30	0. 31	0.26	0.22	0.17	0.11	0.10	0.10	0.10	6.63
10	0.45	0.40	0.36	0.36	0.32	0.29	0.27	0.27	0.21	0.16	0.14	0.11	0.10	0.10	7.49
20	0.43	0.40	0.37	0.34	0.31	0.27	0.26	0.21	0.15	0.11	0.07	0.09	0.10	0.10	8.21
50	0.42	0.41	0.37	0.27	0.29	0.26	0.25	0.25	0.25	0.19	0.19	0.14	0.11	0.11	9.39
							SAR 5								
5	0.45	0.39	0.36	0.24	0.35	0.26	0.30	0.27	0.27	0.26	0.24	0.22	0.17	0.10	8.34
10	0.44	0.40	0.35	0.27	0.35	0.32	0.30	0.26	0.29	0.20	0.20	0.11	0.11	0.10	11.03
20	0.43	0.38	0.36	0.34	0.32	0.31	0.29	0.25	0.25	0.19	0.19	0.11	0.11	0.10	9.75
50	0.42	0.39	0.34	0.30	0.31	0.29	0.27	0.25	0.27	0.17	0.19	0.10	0.10	0.09	10.83
							SAR 10								
5	0.44	0.38	0.33	0.26	0.36	0.32	0.32	0.30	0.26	0.22	0.24	0.15	0.14	0.11	10.55
10	0.43	0.39	0.34	0.25	0.36	0.31	0.31	0.29	0.25	0.21	0.22	0.14	0.12	0.11	16.24
20	0.42	0.40	0.33	0.25	0.35	0.31	0.31	0.27	0.24	0.21	0.20	0.12	0.11	0.10	16.46
50	0.43	0.40	0.34	0.26	0.32	0.30	0.30	0.26	0.24	0.19	0.17	0.11	0.10	0.10	15.47
							SAR 15								
5	0.45	0.40	0.33	0.36	0.36	0.39	0.34	0.32	0.31	0.25	0.26	0.22	0.15	0.12	12.20
10	0.43	0.39	0.34	0.34	0.35	0.37	0.32	0.31	0.30	0.25	0.25	0.21	0.14	0.11	18.56
20	0.44	0.40	0.33	0.35	0.34	0.37	0.31	0.30	0.29	0.24	0.25	0.20	0.12	0.10	24.53
50	0.43	0.38	0.34	0.32	0.34	0.36	0.30	0.29	0.27	0.24	0.24	0.19	0.11	0.09	23.25
							SAR 20								
5	0.44	0.40	0.36	0.39	0.37	0.40	0.36	0.35	0.34	0.30	0.29	0.24	0.16	0.12	16.25
10	0.45	0.40	0.35	0.37	0.36	0.39	0.35	0.34	0.32	0.29	0.27	0.22	0.15	0.11	22.90
20	0.43	0.39	0.35	0.35	0.36	0.37	0.34	0.32	0.31	0.27	0.26	0.21	0.14	0.10	27.74
50	0.43	0.38	0.34	0.34	0.35	0.37	0.32	0.31	0.30	0.26	0.25	0.20	0.12	0.09	27.90
							SAR 30								
5	0.45	0.40	0.36	0.40	0.37	0.41	0.39	0.36	0.35	0.30	0.26	0.24	0.16	0.14	23.60
10	0.44	0.40	0.35	0.39	0.36	0.39	0.37	0.35	0.35	0.29	0.25	0.21	0.15	0.12	28.00
20	0.45	0.41	0.36	0.37	0.35	0.40	0.36	0.34	0.30	0.27	0.24	0.20	0.14	0.11	32.02
50	0.43	0.40	0.36	0.37	0.35	0.37	0.34	0.32	0.26	0.26	0.24	0.19	0.12	0.10	33.29
Normal soil	0.45	0.41	0.37	0.35	0.30	0.29	0.29	0.27	0.22	0.19	0.17	0.14	0.14	0.11	0.59

in water retention was observed only at SAR 30 m $mol^{1/2}$ $L^{-1/2}$ and such increase ranged between 5.7 and 14.3 per cent when TEC varied between 50 and 5 me L^{-1} respectively. Above 20 kPa water retention increased with SAR and decreased with TEC upto 1000 kPa, thereafter increase was slow upto 1500 kPa in clay, whereas, slight reduction in water retention of clay loam soil was observed.

Reduction in DW ranged between 2.8 and 58.3, 3.7 and 48.1 and 6.2 and 75 per cent in clay, clay loam and silt loam soils respectively with progressive increase in SAR from 5 to 30 m $mol^{1/2}$ $L^{-1/2}$ as compared with normal soils (Table 6). Whereas increase in AW ranged between 12.5 and 98, 13.3 and 80 and 11.1 and 61.1 per cent in respective soils. RW in clay soil increased with increasing SAR but in clay loam and silt loam soils it reduced by 4.4 and 11.8 per cent over normal soil with increase in SAR from 2.5 to 15 m $mol^{1/2}$ $L^{-1/2}$. This is possibly because in these soils SAR 30 m $mol^{1/2}$ $L^{-1/2}$ only could raise the water retention at 1500 kPa. Increase in AW of different soils was mainly at the cost of decrease in DW. In clay loam and silt loam soils marginal reduction in RW also contributed towards increase in available water.

Table 6. Effect of water quality on distribution of retained water in different ranges

SAR (m mol$^{1/2}$ L$^{-1/2}$)	TEC (me L^{-1})	Clay D.W.	Clay A.W.	Clay R.W.	Clay loam D.W.	Clay loam A.W.	Clay loam R.W.	Silt loam D.W.	Silt loam A.W.	Silt loam R.W.
		(cm^3 cm^{-3})								
2.5	5	0.29	0.14	0.26	0.28	0.13	0.19	0.15	0.20	0.10
	10	0.24	0.28	0.18	0.21	0.23	0.15	0.16	0.18	0.11
	20	0.30	0.23	0.17	0.15	0.29	0.15	0.16	0.17	0.10
	50	0.33	0.13	0.24	0.24	0.17	0.17	0.16	0.15	0.11
5	5	0.35	0.18	0.18	0.23	0.17	0.19	0.19	0.16	0.10
	10	0.34	0.18	0.18	0.21	0.21	0.16	0.12	0.22	0.10
	20	0.40	0.12	0.17	0.27	0.15	0.16	0.12	0.21	0.10
	50	0.29	0.23	0.17	0.23	0.21	0.15	0.13	0.20	0.09
10	5	0.30	0.22	0.19	0.23	0.20	0.17	0.12	0.21	0.11
	10	0.31	0.22	0.19	0.25	0.17	0.17	0.12	0.20	0.11
	20	0.29	0.22	0.18	0.26	0.17	0.16	0.11	0.20	0.10
	50	0.32	0.20	0.18	0.25	0.18	0.15	0.13	0.20	0.10
15	5	0.24	0.26	0.20	0.18	0.24	0.17	0.06	0.27	0.12
	10	0.26	0.25	0.19	0.18	0.24	0.17	0.06	0.26	0.11
	20	0.27	0.24	0.19	0.20	0.23	0.16	0.07	0.27	0.10
	50	0.27	0.24	0.18	0.20	0.22	0.16	0.07	0.27	0.09
20	5	0.19	0.27	0.22	0.15	0.27	0.18	0.04	0.28	0.12
	10	0.21	0.28	0.20	0.15	0.27	0.17	0.06	0.28	0.11
	20	0.22	0.28	0.19	0.16	0.26	0.16	0.06	0.27	0.10
	50	0.24	0.28	0.18	0.18	0.25	0.16	0.06	0.28	0.09
30	5	0.17	0.30	0.24	0.14	0.25	0.21	0.04	0.27	0.14
	10	0.15	0.30	0.23	0.15	0.26	0.19	0.05	0.27	0.12
	20	0.17	0.30	0.22	0.15	0.26	0.18	0.05	0.29	0.11
	50	0.20	0.30	0.20	0.18	0.25	0.17	0.06	0.27	0.10
Normal soils		0.36	0.16	0.18	0.27	0.15	0.17	0.16	0.18	0.11

Table 7. Effect of TEC (irrespective of SAR) on soil-water constants

Soil Type	TEC — me L^{-1} —	DW	AW	RW
		cm^{-2} cm^{-3}		
Clay	5	0.26	0.23	0.21
	10	0.25	0.25	0.19
	20	0.27	0.23	0.19
	50	0.27	0.23	0.19
	5	0.20	0.21	0.185
Clay loam	10	0.19	0.23	0.17
	20	0.20	0.23	0.16
	50	0.21	0.21	0.16
	5	0.10	0.23	0.115
Silt loam	10	0.095	0.235	0.11
	20	0.095	0.235	0.10
	50	0.10	0.23	0.10

Water retention in different soils did not vary with definite trend under the studied TEC range of 5 to 50 me L^{-1} when compared irrespective of SAR (Table 7). This indicate that the TEC of 50 me L^{-1} was not adequate to suppress the effect of SAR on water retention in studied soils. On the contrary increase in SAR was found to be positively associated with increase in water retention. This may be attributed to the increased thickness of hydrated ion-layers in the inter-layer spacing of clay minerals. This is in agreement with Rowell *et al.* (1969) and Pachepsky (1989). Russo and Bressler (1980) reported increased space in clay platelets with increases in SAR of equilibrating solution at a given pore suction

Statistically significant linear regression relationship (Table 8) of DW with ESP and DI in silt loam indicated ESP and DI induced pore size reduction was the prominent process in this soil. A highly significant linear regression relationship between AW and ESP and AW and DI was observed in different soils. In clay soil highly

Table 8. Linear regression relationship between water constants and ESP or DI of soils

Clay	Clay loam	Silt loam
DW = 0.35 - 0.006 ESP R^2 = 0.90**	DW = 0.28 - 0.006 ESP R^2 = 0.83*	DW = 0.22 - 0.008 ESP R^2 = 0.97**
AW = 0.126 - 0.0087 ESP R^2 = 0.98**	AW = 0.152 + 0.005 ESP R^2 = 0.67	AW = 0.114 + 0.0081 ESP R^2 = 0.93**
RW = 0.181 + 0.0014 ESP R^2 = 0.42	RW = 0.128 - 0.003 ESP R^2 = 0.72	RW = 0.093 + 0.0009 ESP R^2 = 0.74
DW = 1.02 - 0.04 DI R^2 = 0.88*	DW = 0.45 - 0.014 DI R^2 = 0.63	DW = 0.726 - 0.067 DI R^2 = 0.97**
AW = 0.033 DI - 0.37 R^2 = 0.96**	AW = 0.009 DI + 0.05 R^2 = 0.42	AW = 0.064 DI + 0.37 R^2 = 0.95**
RW = 0.005 DI + 0.10 R^2 = 0.39	RW = 0.005 DI + 0.07 R^2 = 0.42	RW = 0.007 DI + 0.039 R^2 = 0.75

*Significant at P = 0.05 **Significant at P = 0.01

significant regression coefficient of AW with ESP or DI might be attributed to increased total surface area resulted from dispersion of soil colloids. In silt loam soil due to less clay content R^2 values were lower than that of clay soil. Though the clay content in clay loam soil was 36.5 per cent, yet very poor regression coefficients between water constants and ESP or DI were observed. This is mainly because in clay loam soil when low SAR (2.5 m $mol^{1/2} L^{-1/2}$) water was added it has reduced the DW and increased AW but when SAR of added water was raised to 10 m $mol^{1/2} L^{-1/2}$, per cent decrease in DW found to be declined and per cent increase in AW also declined. This suggested that in clay loam soil the salinity of water was more effective than that of the sodicity of water in the SAR range between 2.5 and 10 m $mol^{1/2} L^{-1/2}$. A poor regression of RW with ESP or DI in different soils suggested that the dispersion was not a prominent process at the suction of 1500 kPa or pore size reduction below 2 $\times 10^{-4}$ mm hardly occurred within the studied ranges of SAR and TEC.

References

Acharya, C. L. and Abrol, I. P. (1978). Exchangeable sodium and soil-water behaviour under field conditions. *Soil Sci*. **125**: 310-319.

Adiku, S.G.K., Dayananda, P.W.A., Rose, C.W. and Dowuona, G.N.N. 1997. An analysis of the within season rainfall characteristics and simulation of the daily rainfall in two savanna zones in Ghana. Agricultural and Forest Meteorology.Vol 86. DOI: 10.1016/S0168-1923(96)02414-8.

Bruce, R.R. and Luxmoore, R.J. (1986) *Methods of soil analysis*. Part I. 2nd ed. Agronomy No. 9. American Society of Agronomy, Madisan Wisconsin, USA. p. 663.

Central Intelligence Agency World Factbook, 2011. http://www.theodora.com/wfbcurrent/ghana/ghana_economy.html

Choukr-Allah, R. 1997.The Potential of Salt-Tolerant Plants for Utilization of Saline Water.Options Méditerranéennes, Sér. A /n031, 1997 Séminaires Méditerranéens. Institut Agronomique et Vétérinaire Hassan II Agadìr, Morocco.

González-Núñez, L.M., Tóth, T. and García, D. 2004. Integrated Management for the Sustainable Use of Salt Affected Soils in Cuba. Vol 20. Numero 040-Universidad Juarez Autonoma de Tabasco, illahermosa, Mexico, pp. 85102

Malik, M. Mustafa, M.A. and Letey, J. (1992) Effect of mixed Na-Ca solutions on swelling, dispersion and transient water flow in unsaturated montmorillonitic soils. *Geoderma* **52**: 17-28.

Mustafa, M.A. and Letey, J. (1969). The effect of two non-ionic surfactants on aggregate stability of soils. *Soil Sci*. **107**: 343-347.

Pachepsky, Y.A. (1989). Effect of the composition of the soil solution and exchange cations on water retention and hydraulic conductivity. *Soviet Soil Sci.* **20 (4)**: 90-103.

Reitemeir, R.F. (1946). Effect of moisture content on the dissolved and exchangeable ions of soils of arid regions. *Soil Sci.* **61**: 195-214.

Rietz, D.N. and Haynes, R.J. 2003.Effects of Irrigation Induced Salinity and Sodicity on Soil Microbial Activity. Soil Biology and Biochemistry – Elsevier. DOI:10.1016/S00380717(03)00125-1

Rowell, D. L., Payne, D. and Ahmad, N. (1969). The effect of the concentration and movement f solutions on the swelling, dispersion and movement of clay in saline and alkali soils. *J. Soil Sci*. **20**: 176-188.

Russo, D. and Bressler, E. (1980) *Agrochemicals in soils*, Pergman Press, New York. pp. 287.

Sandhu, S. S., Acharya, C. L. and Abrol, I.P. (1980) The effect of exchangeable sodium on the water retention, transmission and modulus of rupture of a soil. *Proc. Int. Symp. Salt Affected Soils*, Karnal, pp. 185.

Siadat, H. 1998. Iranian Agriculture and Salinity. Soil & Water Research Institute of Iran. 1998. http://www.unu.edu/env/workshops/iran-1/02Siadat%20Paper.doc

Stride, G.T. and Ifeka, C. 1971. Peoples and Empires of West Africa: West Africa in history, 1000-1800. Africana Publishing Company.

Tucker, B.M. (1971). Basic exchangeable cations in soils. *Tech. Paper No. 8*, CSIRO, Aust. Div. Soils.

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