USING BRACKISH WATER ON NORMAL AND SALT-AFFECTED SOILS IN PAKISTAN: A REVIEW

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Salt-affected is a general term for saline, saline-sodic and sodic soils and the term brackish is mostly used for waters having hazardous levels of EC, SAR and/or RSC. Salient properties under each of the categories are shown in Table 1 for soil and in Table 2 for water proposed by different agencies. A detailed discussion on water quality for irrigation is given by Ayers and Westcot (1985) and Rhoades and Loveday (1990) under different situations of the world.

Table 1. Characteristics of salt-affected soils

Category	ECe ($dS\ m^{-1}$)	SAR ($mmol\ L^{-1})^{1/2}$	pHs
Saline	> 4	< 13	< 8.5
Saline-sodic	> 4	> 13	± 8.5
Sodic	< 4	> 13	> 8.5
Normal soil	< 4	< 13	< 8.5

(Source: U.S. Salinity Lab. Staff, 1954).

1. EXTENT OF PROBLEM SOILS AND WATERS

1.1. Soils: There is a lot of controversy about the extent of salt-affected soils (Muhammed, 1981), especially the one that falls within the canal commanded area, CCA (Mian & Ashraf, 1980). The difference in the extent of area appears to be due to different methods of appraising the soils by different agencies (Hussain, 1970) and even the time of survey may be one source of this difference. The more acceptable figures of the extent of salt-affected soils are those reported by Muhammed (1983) as shown in Table 3.

1.2. Waters: The quality of groundwater was assessed on the basis of total soluble salts (TSS) in the beginning. The extent of areas possessing groundwater of different salinities within 350 feet is shown in Table 4 (Ahmad & Chaudhry, 1988). It may also be noted that groundwater of the reported quality does not exist within the full depth of 350 feet. Generally, in all the areas top layers near to soil surface is relatively better and useable except at certain sites but groundwater salinity increases with depth. However, little work has been planned and accomplished to exploit this better quality shallow groundwater. Of course, the National Commission on Agriculture (NCA, 1987) has emphasised the issue. Moreover, the most hazardous property of the water, RSC and SAR, has altogether been neglected in the survey but scientifically needs emphasis even more than TSS. Overall, about 40 MAF of groundwater of variable quality is being pumped and used for crop production in the Indus Plains (NCA, 1987). Furthermore, the Ca:Mg and Ca:total cation ratios in water or soil have to be investigated for long term effects on soils and crops (Khan, 1975; Faiz-ullah, 1989; Ghafoor et al., 1990 a, b and 1991).

Other reports indicate that about 25, 25 and 50% of the present tubewell discharge in the Punjab is useable, marginal and unfit, respectively for irrigation (Malik, 1983; Malik *et al.*, 1984). So, 75% of the tubewell water needs some additional management for sustained crop production. Distribution of tubewells is shown in Table 5.

2. PREREQUISITES OF BRACKISH WATER USE

Good subsurface drainage and deep groundwater (>3m) are essential for efficient and longtime use of brackish waters. Horizontal (surface drains, subsurface drains, tiles drains) or vertical drainage (tubewells) may be required for lowering the subsoil water. Apart from the resalination in arid/semiarid climates, shallow watertable results in wastage of resource through unproductive evaporation (Asghar *et al.*, 1952 & 1962; Muhammed, 1975 & 1983) and can also induce oxygen stress. It also causes nutritional disturbances for plant growth along with production of toxic chemicals under the anaerobic conditions.

The brackish water can be utilized for growing crops by following certain site-specific treatments since such waters may vary considerably with respect to the concentration and type of salts. The properties of soils receiving such waters also vary with respect to the structure, pore size distribution, spatial arrangement of various pore sizes and presence as well as depth of dense layer(s) in the subsoil. The maintenance of leaching fraction (LF) is considered an important factor for good management of poor quality waters. However, higher amount of irrigation water to achieve the required LF can be applied as frequent and light irrigations or as infrequent and heavy irrigations depending on the crop grown and other factors mentioned above.

If the groundwater is deep and the fields are levelled, rain water is a natural source for the periodic leaching of soil salinity. If the groundwater is shallow (within 1m), the *monsoon* rain may become a source of waterlogging. The problem may become more intense if water quality is very poor and soils are fine textured. However, for sodic and saline-sodic soils, an economical Ca-source is essential if to be irrigated with brackish water.

3. EFFECT OF BRACKISH WATERS ON SOILS AND PLANT GROWTH

3.1. Unamended water on normal soils: Under average management practices, brackish irrigation water increases the soil EC_e, SAR/ESP along with physical deterioration of soils. Consequently, most of the crops suffer badly and glycophytes may even fail or at least become uneconomical to grow (Hussain and Ahmad, 1966; Bhatti *et al.*, 1977 & 1981; Khan *et al.*, 1986; Hussain and Asghar, 1988a & b). However, some cultural practices may help for better soil and plant conditions.

The literature indicates that soil SAR increased significantly in direct proportion to SAR_{iw}. The EC_e and pHs also increased relatively at a lower rate (Qayyum, 1973; Qayyum and Niazi, 1975; DeMooy *et al.*, 1975; Haider and Farooqi, 1975; Haider *et al.*, 1976). Here maize germinated satisfactorily with waters of TDS < 1500 ppm and SAR_{iw} < 20. However, Hussain (1985) reported that the yields of maize, berseem, cotton and sorghum were not affected statistically when grown in the above sequence using waters of 0.86, 2.0, 2.5 and 3.0 dS m^{-1} EC with SAR of 3.7, 20.0, 24.0 and 26.8, respectively.

For medium and coarse textured soils, a water having 830 ppm TDS, < 7 SAR and < 1.25 me L^{-1} RSC did not create any problem regarding soils and crops (Chaudhry & Rana, 1975). Higher values of these parameters for irrigation water caused an increase in soil deterioration but was manageable up to 12 years for a variety of agronomic crops simply by the use of FYM. Similar results have been reported by Hussain and Asghar (1988 a & b) from their field studies. But in a pot experiment, FYM up to 20 tons ha^{-1} failed to improve maize and wheat yields when irrigatd with saline (EC = 1-4 dS m^{-1}) or sodic (SAR = 5-35) waters (Salim *et al.*, 1986 & 1987). Haider and Farooqi (1974), Haider and Hussain (1981) and Qayyum and Sabir (1975 & 1976) studied and confirmed the safe use of brackish waters having TDS < 2000 ppm, SAR < 10 and RSC < 2.5 me L^{-1} for the production of field crops on medium textured soils provided good management was practised. Chaudhry and Rafiq (1983) and Ali *et al.* (1981) also expressed similar views regarding only the TDS of irrigation water.

Some pot experiments (Muhammed *et al.*, 1977; Muhammed and Rauf, 1983; Yasin, 1983; Yasin *et al.*, 1988) have shown good promise of maintaining a leaching fraction (0.1-0.19) as a good management practice. Under field conditions (Bhatti *et al.*, 1977; Bhatti, 1986), however, at low LF (< 0.20) there was little check on the build up in soil EC_e and SAR. Even the soil became sodic (SAR > 13) within about four years under canal water treatment with 10 and 20% leaching requirement (LR). But at higher LR (30-60%), the practice worked fairly to help grow salt tolerant crops. It appears that under such a high LF, most of the water evaporated rather passing through the soil which resulted in accumulation of salts in the surface layer of soil. Mixing canal water with brackish water to a final total dissolved salts (TDS) of 1000 ppm produced reasonable crop yields. Anyhow, Mona Reclamation Experiment Projct Staff (MREPS) obtained good yields of wheat and sorghum being irrigated with Bhera drain water (EC = 448-832 ppm, SAR = 1.3-5.6, RSC = 0.0-2.4 me L^{-1}) by maintaining LR of 15-30% (Chaudhry *et al.*, 1987; Haider and Hussain, 1981).

Crop rotations without including a high-water requirement crop were not suitable (Haider *et al.*, 1973; Rehman and Hussain, 1981) to arrest the soil sodication and salination because of brackish water irrigation. Almost similar conclusions have been drawn by Bhatti (1986). Of course, planting cotton on slopping beds was found better than flat sowing (Chaudhry and Haider, 1983).

In other studies (Ahmad *et al.*, 1985 & 1986; Ahmad and Abdullah, 1981), *L. fusca*, *P. turgidum* and sesbania were grown on sandy soils. They applied diluted sea water (final EC_{iw} = 4.5-14.0 dS m^{-1}) for irrigation. There was an increase in Na, Ca and Mg concentration in plants. Plant species differed in salt tolerance. However, maximum biomass production was recorded in late summer, i.e. when the temperature was relatively lower and the 'monsoon' season was over. NIAB (1987) and Akhtar *et al.*, (1988) reported good improvement in saline-sodic soil properties and biomass of *L. fusca* under field conditions grown with brackish water.

The above discussion indicates that most of the experiments have been conducted at MREP. There were small number of combinations of EC, SAR and RSC at their different levels. The other factors, like soil texture, LF, crop rotation, manure application etc. were not well elaborated. This necessitates that some detailed studies should be conducted under different agro-ecological zones of the Punjab/Pakistan to reach at certain water quality parameters.

Table 2. Criteria for the water quality

a. U.S. Salinity Lab. Staff (1954)

Category	EC (μ mhos cm^{-1})	SAR	Remarks
Low problem	< 250	< 10	Little likely-hood of salinity and sodicity development.
Medium problem	250-750	10-18	There will be appreciable sodium hazard in fine textured soils, especially for high cation exchange capacity soils. Water can be used on coarse textured or organic soils with good permeability.
High problem	750-2250	18-26	This water may produce harmful levels of exchangable sodium in most soils. Application of ammendments, good drainage, high leaching and addition of organic matter may become essential.
Very high probelm	> 2250	> 26	This water is generally unsatisfactory. Application of gypsum may make the use of this water feasible occasionally.

b. Yunus (1977)

Category	TSS (mg L^{-1})	SAR	RSC (me L^{-1})	Remarks
Suitable	< 1000	< 10	< 2.5	For Indus Plains of
Marginal	1000-2000	10-18	2.5-5.0	Pakistan, WAPDA
Hazardous	> 2000	> 18	> 5.0	recommendations.

c. Dept. of Agriculture, Punjab

Suitable	< 800	< 8	< 1.25
Marginal	800-1000	8-10	1.25-2.5
Hazardous	> 1000	> 10	> 2.5

d. Directorate of Land Reclamation

	TSS (mg L^{-1})	SAR	RSC (me L^{-1})
Suitable	Up to 1000	Up to 10	Up to 2.5

e. FAO (Reported by Yunus, 1977)

Category	EC (μ mhos cm^{-1})	SAR_{adj}	Specific Ion Toxicty		
			Na	Cl	B
			-------- me L^{-1}	---------	(mg L^{-1})
No problem	< 700	< 16	< 3	4	0.75
Increasing problem	700-3000	16-24	3-9	4-10	0.75-2.0
Severe problem	≥ 3000	≥ 24	≥ 9	≥ 10	≥ 2.0

f. FAO (Ayers and Westcot, 1985)

Potential irrigation problem	Degree of restriction on use		
	None	Moderate	Severe
Salinity, EC_{iw} (dS m^{-1})	< 0.7	0.7-3.0	> 3.0
Infiltration			
SAR = 0-3 & EC_{iw} (dS m^{-1})	= > 0.7	0.7-0.2	< 0.2
" = 3-6	= > 1.2	1.2-0.3	< 0.3
" = 6-12	= > 1.9	1.9-0.5	< 0.5
" = 12-20	= > 2.9	2.9-1.3	< 1.3
" = 20-40	= > 5.0	5.0-2.9	< 2.9

g. Hussain (1978)

		TDS (mg L^{-1})	SAR	RSC (me L^{-1})
Good	a.	< 1000	< 10	< 2.5
	b.	< 750	< 7	< 2.5
Marginal	a.	1000-2000	10-15	2.5-5.0
	b.	750-1500	7-12	2.5-5.0
Hazardous	a.	> 2000	> 15	> 5.0
	b.	> 1500	> 12	> 5.0

a. For optimum management conditions.
b. For existing on-farm management conditions.

h. Sheikh (1989)

Category	EC (μ mhos cm^{-1})	SAR	RSC (me L^{-1})	Remarks
Useable	0-1500	0-10	0.0-2.5	To be used as such or on dilution with canal water.
Marginal	1500-3000	10-18	2.5-5.0	To be used after mixing with canal water in 1:1 ratio.
Hazardous	> 3000	> 18	> 5.0	To be used after higher dilution with canal water or chemical amendments.

i. Republic Engineering Corporation (1974)

Category	EC (dS m^{-1})	SAR	Remarks
Good	< 1.50	0-10	Safe to use under average management.
Marginal	1.50-2.70	10-14	To be used after mixing with canal water in the ratio of 1:1.
Hazardous	> 2.70	> 14	To be used under special management practices like higher dilution, application of amendments and higher leaching.

Otherwise formulation of water quality standards (Table 2) is a natural consequence but of no value to the farmers unless supported by research results.

3.2. Amended water on normal soils: Brackish water passed through gypsum stone-lined water courses (Ahmad *et al.*, 1979; Ahmad and Kemper, 1976; Kamper *et al.*, 1975; Hanif *et al.*, 1975; Qureshi *et al.*, 1975) can safely be applied to raise the crops from normal soils. Even such water treatments proved useful for reclamation of saline-sodic fields (Hussain *et al.*, 1986; Ghafoor *et al.*, 1987). Improvement in water quality after passing through the lined water courses is shown in Table 4.

One irrigation with unamended tubewell water and one to two with amended water have been reported safe as far as soil properties are concerned (Qureshi *et al.*, 1977). However, any number of irrigations were found satisfactory for the wheat yield. Similar results have been reported for wheat (Aslam *et al.*, 1977; Salim *et al.*, 1986 & 1987; Cheema *et al.*, 1988) and maize (Hanif *et al.*, 1975; Salim *et al.*, 1986 & 1987; Cheema *et al.*, 1988 & 1989).

Table 3. Extent and categories of salt-affected soils (thousand acres)

Province	Saline	Saline-sodic	Sodic	Total	Gypsiferrous saline-sodic
Punjab	1245.8	5142.0	-	6529.1	141.3
Sindh	3315.4	2348.4	69.7	6571.2	837.7
NWFP	1238.9	35.6	-	1289.9	15.4
Balochistan	432.3	319.5	-	974.2	222.4
Pakistan	6232.4	7845.5	69.7	15364.4	1216.8

(Source: Muhammed, 1983)

Table 4. Areas within different groundwater salinity

Region	Gross area (MA)	% of area with TDS (ppm or mg L^{-1})			
		up to 1000	1000-1500	1500-3000	> 3000
			a. Up to 350 feet depth		
Punjab	24.32	55.7	13.8	13.5	17.0
Sindh + Balochistan	15.43	9.8	5.3	8.8	76.1
NWFP	0.99	82.4	5.2	12.4	-
Pakistan	40.73	38.9	10.4	11.9	38.9
			b. Up to 125 feet depth		
Punjab	24.32	65.4	12.2	9.8	12.6
Sindh + Balochistan	15.43	17.2	6.6	13.8	62.4
NWFP	0.99	82.4	5.2	12.4	-
Pakistan	40.73	47.5	9.9	11.4	31.2

(Source: Ahmad & Chaudhry, 1988)

Table 5. Province-wise distribution of tubewells in Pakistan

Province	Private tubewells	Public tubewells	Total
Punjab	166361	10535	176896
Sindh	*	*	17356
NWFP	4493	735	5228
Balochistan	7453	131	7584
Pakistan	178307	11401	207064

Total discharge40 MAF.

* Data not available

(Source: Ahmad and Chaudhry, 1988)

Haider and Farooqi (1972), Haider *et al.* (1978), Hussain *et al.* (1979 & 1981) and Salim *et al.* (1986) investigated the soil-applied gypsum powder on the basis of gypsum requirement (GR) of water. They recommended that 50-75% GR of water has to be met with in order to avoid the deterioration of soil as well as yields of wheat and maize. Similar views have been expressed by Jilani *et al.* (1988 & 1989) for maize and by Cheema *et al.* (1988 & 1989) for wheat production.

Chaudhry *et al.* (1984a and 1985) obtained better paddy yield if water was allowed to pass through a gypsum stone lined water course than that with soil-applied gypsum powder, both the rates being equivalent to 100% GR of water. However, wheat yield was better with soil application. In spite of an increase in SAR, EC_e and pHs of the control plots. Similar views were expresed by others (Chaudhry *et al.*, 1986 b; Muhammed and Amin, 1965).

Table 6. Water amendment through gypsum stone-lined water course

Un-amended water			Amended water			Source
EC ($dS\ m^{-1}$)	SAR	RSC ($me\ L^{-1}$)	EC ($dS\ m^{-1}$)	SAR	RSC ($me\ L^{-1}$)	
3.6	21.0	11.5	4.0	15.8	6.0	Qureshi *et al.*, 1975
3.5	19.5	12.9	3.9	12.0	6.5	Qureshi *et al.*, 1977
1.8	10.2	7.1	2.1	8.7	4.6	Ghafoor *et al.*, 1987

Ahmad and Kemper (1976) and Kemper *et al.* (1975) concluded that an increase in Ca concentration was inversely proportional to the square root of the water flow velocity and the size of stones in the water course. Ghafoor *et al.* (1988a & b, 1989) indicated that gypsum dissolution increased generally with increasing the particle fineness and EC of synthetic solutions. Solubility was higher in NaCl than that in solutions of salt mixture (NaCl, Na_2SO_4, $CaCl_2$, $MgSO_4$). These results indicate that in high SAR water, dissolution of gypsum stone or soil-applied coarse gypsum particles may work satisfactorily.

Treatment of water (EC = 1624 ppm, SAR = 8.2, RSC = 3.4 me L^{-1}) with $CaCl_2$, gypsum, H_2SO_4 and HCl at rates equivalent to water GR in pots produced similar maize fodder on coarse, medium and fine textured soils during the first year. During the 2nd year, $CaCl_2$ produced better yield than that with the other amendments (Jilani *et al.*, 1988). In another pot experiment, maize fodder yield with 1 brackish and 2 canal water irrigations and vice versa were statistically similar from coarse, medium and fine textured soils. Even 3 irrigations with tubewell brackish water and one with canal water and vice versa produced similar maize fodder.

In a field experiment (Cheema *et al.*, 1988) with soil-applied H_2SO_4, gypsum, S, $CaCl_2$ and HCl at rates equivalent to 100% GR of the total water applied obtained similar wheat yield. Meeting 50% water GR with gypsum when sodic and canal water irrigations varied from 1 to 3, in all possible combinations, also produced statistically similar yield of wheat.

Overall, the review indicates that water or soil-application of gypsum equivalent to water GR is a prerequisite and economical for growing crops on normal soils with brackish water. Although depending upon the crop and soil type, rate of application may become different. Anyhow, there is no clue about the quality of the produce on long term basis. Other Ca sources, directly or indirectly, may be used if found economical and application is feasible.

3.3. Unamended brackish water on treated saline-sodic soils: Field experiments have indicated that when saline-sodic soils were treated with gypsum, H_2SO_4, HCl and $CaCl_2$ at rates equivalent to soil GR (50-100% GR), a brackish water (EC = 1.8 dS m^{-1}, SAR = 10.0, RSC = 7.1 me L^{-1}) reclaimed the Khurrianwala and Gandhra soils within 1.5 and 2.5 years, respectively. With subsoiling the Khurrianwala sandy loam/sandy clay loam soil was improved with rice-wheat crops but in a longer period of time (Ghafoor *et al.*, 1985 a, b and 1986; Muhammed and Ghafoor, 1986; Muhammed *et al.*, 1988). Bhatti (1986) also concluded that brackish water up to TDS of 2000 ppm can be used to grow maize, sorghum and millet on a soil amended with H_2SO_4 or gypsum at rates equivalent to the soil GR. However, gypsum application has been found economical in all the above studies. Some decrease in EC_e, and SAR of coarse textured soils but an increase in EC_e and SAR of fine textured saline-sodic soils was reported by Haider and Farooqi (1975).

Haider and Hussain (1976) reported that pressmud application to a saline-sodic soil significantly reduced the soil SAR. Water infiltration rate increased statistically. Yield of wheat, cotton, sorghum, maize, alfalfa and clover increased considerably with pressmud treatment being irrigated with high-SAR waters. Similarly, Haq and Dabin (1981) observed that fresh alfalfa green manure (GM) was a good soil amendment. The increased soil infiltration with GM resulted due to Ca from dissolution of soil lime ($CaCO_3$) in response to CO_2 evolution during decay process. This Ca proved sufficient to counteract the ill-effects of marginal quality irrigation water. In other laboratory experiments (Ghafoor *et al.*, 1988a & 1989), with high EC_e and SAR waters (EC = 0.6-4.0 dS m^{-1}, SAR = 6-30) without RSC successfully reclaimed a saline-sodic soil receiving 16-25 mesh gypsum powder equivalent to 100% GR for 15 cm soil columns only.

These studies lead to conclude that brackish water can be safely used for growing salt tolerant crops, a common practice during reclamation of salt-affected soils, under both the laboratory and field conditions. However, in none of the investigations, quality of produce, period for which the soil reclamation will last and groundwater pollution has been monitored. Similarly, because of the centralized sites of experimentation at Mona and Faisalabad, results may not be applicable on a wider range of soil, water and crop types.

3.4. Amended water on treated saline-sodic soils: Very few field experiments have been reported in literature. About 183 metres long water course was lined with gypsum stones, weighing 5-30 kg. The water passed through it (Table 6) was used for growing rice-wheat crops during reclamation of the Gandhra series treated with gypsum @ 75% soil GR with and without subsoiling. Under the agro-climatic conditions of this field experiment (Hussain *et al.*, 1986; Ghafoor *et al.*, 1987), gypsum (-70 mesh) with and without subsoiling remained the best treatment for soil improvement and crop yields from 1981-1984 using water of EC = 1.8 dS m^{-1}, SAR = 10.0 and RSC = 7.1 me L^{-1}.

3.5. Using brackish water with different Ca:Mg ratios: Khan (1975) pointed out that high Mg in soils may be considered for their classification. Chaudhry *et al.* (1986a) observed maximum increase in infiltration rate and a decrease in SAR and EC_e with water having Ca:Mg ratios of 2:1 and 1:1. There was a considerable increase in soil SAR and EC_e with water of 1:2 ratio and this ratio also decreased wheat and paddy yields significantly. However, Faizullah (1989) obtained no response regarding wheat yield and ESP of a saline-sodic soil being irrigated with brackish water (EC = 2 dS m^{-1}, SAR = 12) with Ca:Mg ratios of 4:1, 2:1, 1:2, 1:4 and 1:6. In another experiment, Ghafoor *et al.* (1990 a, b & 1991) have reported safe use of high Mg water for soil reclamation but there were some adverse effects on the crop growth by higher proportion of Mg in irrigation water.

3.6. Role of fertilizer application for using brackish water: Chaudhry *et al.* (1984b) applied nitrogen @ 75, 125 and 175 kg ha^{-1} and water with TDS of 736, 1056, 1408 and 2000 ppm for growing rice and wheat. They observed an increase in infiltration rate, but yields of paddy and wheat decreased by 7 to 17% as the TDS increased from 736 to 2000 ppm.

Use of Ca-containing and Ca-free N and P fertilizers for growing rice and wheat crops during reclamation using brackish water (EC = 1.8 dS m^{-1}, SAR = 10.0, RSC = 7.1 me L^{-1}) did not prove their worth (Hussain, 1982; Ali, 1984). The soil amelioration was just equivalent to the Ca contents in the fertilizers, irrigation water and from the dissolution of soil lime.

Some improvement in the yields of wheat and paddy has been reported with the higher doses of NPK fertilizers on saline-sodic medium to coarse textured soils during reclamation using water of unknown quality at Pindi Bhattian (Anonymous, 1988). NIAB (1987) obtained good yield of Kallar grass on a salt-affected soil (EC_e = 13.6 dS m^{-1}, SAR = 175, pHs = 10.3) grown with water of EC = 1.4 dS m^{-1}, SAR 7.6, RSC = 9.7 me L^{-1} and fertilized with 62 kg N ha^{-1}.

3.7. Miscellaneous studies: It is generally accepted hypothesis that with increasing depth from the surface and distance from a river, there is an increase in brackishness (EC, SAR) of groundwater, particularly in arid and semiarid regions. It could be reasonable to assume that continuous pumping of groundwater may deteriorate the quality of water. However, limited studies (Hussain *et al.*, 1980; Hussain and Asghar, 1988 a & b) have indicated no such deterioration in water quality.

4. Conclusions: On the basis of the literature reviewed, it could be concluded that most of the studies are site-specific and short term in nature and indicate inconsistencies for such an experimentation which is of primary importance to generalize the research results. However, findings may be summarized as under:

1. Brackish waters showed different adverse effects depending upon the soil

type, crop nature and management practices on normal soils. Crops having high-water requirements or more salt tolerance were less adversely affected on coarse textured soils.

2. Brackish waters improved the soil properties and growth of crops during early phases of reclamation of salt-affected soils, without the application of amendments. Results on long term effects are not available.
3. Using amended water, either passed through gypsum stone-lined water course or applying an equivalent amount of amendments, both on the normal and salt-affected soils, has shown considerable usefullness.
4. Brackish water for salt-affected soils, treated with an amendment @ soil GR, has shown good results but necessitates further experimentation.
5. Use of brackish waters, farming systems, role of fertilizers and other management practices etc. like planting techniques, irrigation methods, tillage practices still need studies on a wider scale particularly at farmer level.

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