THE ATRIUM, SOUTHERN GATE, CHICHESTER, WEST SUSSEX P019 8SQ

*****IMMEDIATE RESPONSE REQUIRED*****

Your article may be published online via Wiley's EarlyView® service (http://www.interscience.wiley.com/) shortly after receipt of corrections. EarlyView® is Wiley's online publication of individual articles in full-text HTML and/or pdf format before release of the compiled print issue of the journal. Articles posted online in EarlyView® are peer-reviewed, copy-edited, author-corrected, and fully citable via the article DOI (for further information, visit www.doi.org). EarlyView® means you benefit from the best of two worlds - fast online availability as well as traditional, issue-based archiving.

Please follow these instructions to avoid delay of publication

☐ **READ PROOFS CAREFULLY**

- This will be your only chance to review these proofs**. Please note that once your corrected article is posted online, it is considered legally published, and cannot be removed from the Web site for further corrections.**
- Please note that the volume and page numbers shown on the proofs are for position only.

☐ **ANSWER ALL QUERIES ON PROOFS** (Queries for you to answer are attached as the last page of your proof.)

- List all corrections and send back via e-mail to the production contact as detailed in the covering e-mail, or mark all corrections directly on the proofs and send the scanned copy via e-mail. Please do not send corrections by fax or in the post.

☐ **CHECK FIGURES AND TABLES CAREFULLY**

- Check size, numbering, and orientation of figures.
- All images in the PDF are downsampled (reduced to lower resolution and file size) to facilitate Internet delivery. These images will appear at higher resolution and sharpness in the printed article.
- Review figure legends to ensure that they are complete.
- Check all tables. Review layout, title, and footnotes.

☐ **COMPLETE CTA (if you have not already signed one)**

- Please send a scanned copy with your proofs and post your completed original form to the address detailed in the covering e-mail. **We cannot publish your paper until we receive the original signed form.**

☐ **OFFPRINTS**

- 25 complimentary offprints of your article will be dispatched on publication. Please ensure that the correspondence address on your proofs is correct for despatch of the offprints. If your delivery address has changed, please inform the production contact for the journal - details in the covering e-mail. Please allow six weeks for delivery.

Additional reprint and journal issue purchases

- Additional **paper reprints** (minimum quantity 100 copies) are available on publication to contributors. Quotations may be requested from mailto:author_reprints@wiley.co.uk. Orders for additional paper reprints may be placed in advance in order to ensure that they are fulfilled in a timely manner on publication of the article in question. Please note that offprints and reprints will be dispatched under separate cover.
- PDF files of individual articles may be purchased for personal use for $25 via Wiley's Pay-Per-View service (see http://www3.interscience.wiley.com/aboutus/ppv-articleselect.html).
- Please note that regardless of the form in which they are acquired, reprints should not be resold, nor further disseminated in electronic or print form, nor deployed in part or in whole in any marketing, promotional or educational contexts without further discussion with Wiley. Permissions requests should be directed to mailto:permreq@wiley.co.uk
- Lead authors are cordially invited to remind their co-authors that the reprint opportunities detailed above are also available to them.
- If you wish to purchase print copies of the issue in which your article appears, please contact our Journals Fulfilment Department mailto:cs-journals@wiley.co.uk when you receive your complimentary offprints or when your article is published online in an issue. Please quote the Volume/Issue in which your article appears.

LAND DEGRADATION & DEVELOPMENT

Land Degrad. Develop. **17**: 1–9 (2006)

Published online in Wiley InterScience (www.interscience.wiley.com) **DOI**: 10.1002/ldr.776

FODDER PRODUCTION AND SOIL HEALTH WITH CONJUNCTIVE USE OF SALINE AND GOOD QUALITY WATER IN USTIPSAMMENTS OF A SEMI-ARID REGION

R. K. YADAV[1]*, S. P. SINGH[Q1][1], D. LAL[2] AND A. KUMAR[3] Q1

[1]*National Bureau of Soil Survey & Land Use Planning, Regional Centre, New Delhi, India*
[2]*Central Institute for Research on Buffaloes, Hisar 125004, India*
[3]*Central Soil Salinity Research Institute, Karnal 132001, India*

Received 6 August 2005; Revised 23 June 2006; Accepted 30 August 2006

ABSTRACT

Food and fodder shortage in arid and semi-arid regions force farmers to use marginal quality water for meeting water requirement of crops which result in low quality, reduced production and adverse impact on soil properties. A field study on loamy sand (Hyperthermic Typic Ustipsamments) saline soil was conducted during 1999–2001 at Central Institute for Research on Buffaloes, Hisar. This involved assessment of effects of conjunctive use of saline water, EC = 4·6–7·4 dSm^{-1}, SAR = 14–22 ((mmol^{-1})$^{1/2}$ with good quality water on five fodder crop rotations: oat-sorghum (*Avena sativa-–Sorghum bicolor*), rye grass–sorghum (*Loleum rigidum—Sorghum bicolor*), Egyptian clover—sorghum (*Trifoleum alexandrinum—Sorghum bicolor*), Persian clover—sorghum (*Trifoleum resupinatum—Sorghum bicolor*) and Indian clover–sorghum (*Melilotus indica—Sorghum bicolor*) and certain soil properties associated with it. Leguminous winter fodder crops were more sensitive to poor quality water use. Reductions in fodder yield with use of saline water alone throughout season were 85, 68, 54, 42, 36 and 26 per cent in Indian clover, Egyptian clover, Persian clover, oat, rye grass and sorghum respectively as compared to good quality water. Leguminous fodder crops produced protein rich (12–14 per cent) and low fibre (18–20 per cent) fodder as compared to poor quality grassy fodder under good quality water irrigation but their quality deteriorated when saline water was used. These leguminous crops accumulated proportionately higher Na^{+} (1·58 per cent) resulting in adverse impact on their growth as compared to grassy fodder crops. Higher soil salinity (12·2 dSm^{-1}), SAR = 20 (mmol^{-1})$^{1/2}$ was recorded with saline water irrigation; and slight adverse impact was noticed on infiltration rate and contents of water dispersible clay. Alternate cyclic use of canal and saline water could be an option for fodder production under such conditions. Copyright © 2006 John Wiley & Sons, Ltd.

KEY WORDS: fodder production; saline irrigation; water dispersible clay; infiltration rate; loamy sand; sodium adsorption ratio (SAR); proximate quality; semi-arid; India

INTRODUCTION

Agricultural production in arid and semi-arid regions depends on better water management. Due to inadequacy of good quality water in these regions, farmers are compelled to use poor quality ground water to meet irrigation requirement of crops. Ground water surveys indicate that poor quality water utilisation in different Indian states range from 32 to 84 per cent of total surface water development (Tyagi and Minhas, 2002). Further, the twin problem of water logging and salinity due to seepage and percolation has emerged in many canal commands lacking in natural drainage. For successful crop production under such conditions, leaching with subsurface drainage is required for flushing out salts from root zone. However, disposal of saline drainage effluents generated by drainage systems is again a major problem in land-locked areas, thus necessitating their *in situ* disposal/use alternatives.

* Correspondence to: R. K. Yadav, NBSS&LUP, Regional Centre, PUSA, New Delhi 110012, India.
E-mail: rajcssri@yahoo.co.in

With impending severe water scarcity and competition from more paying sectors of economy, it is imperative that agriculture will have to increasingly depend upon marginal quality waters. However, indiscriminate use of poor quality waters in the absence of proper soil-water-crop management practices pose serious risks to crop production and quality along with soil health and environment. Development of salinity and sodicity as a consequence of irrigation with poor quality water not only reduce crop productivity but also deteriorate the quality of produce from a limited choice of crops. The crops grown for grain production are more sensitive to irrigation water quality in comparison to fodder crops (Mass and Hoffman, 1977; Troug and Roberts, 1992). The adverse impact of poor quality water use on soil health depends on soil texture and climatic conditions (Singh and Poonia, 1980).

This adverse impact on soil health and crop production could be mitigated to some extent by conjunctive use of good and poor quality water in cyclic mode (Bradford and Letey, 1992; Yadav *et al.*, 2004). Hence, the present investigation was carried out to quantify the impact of conjunctive use of saline water on different fodder production systems, their quality and certain physico-chemical properties of loamy sand soils of semi-arid zone under monsoonal climate.

MATERIALS AND METHODS

Study Area and Climate

A field study was carried out on alluvial loamy sand (Hyperthermic Typic Ustipsamments) saline soil at Central Institute for Research on Buffaloes, Hisar (29°10′ N, 75°46′ E, 215m asl) for 3 yr during 1998–99 to 2000–01. The experimental site represents semi-arid monsoonal climate characteristics with 70–75 per cent of annual 425 mm rainfall occurring during July–September (Figure 1). Potential evaporation of the area generally exceeds rainfall.

Experimental Details

The experiment was laid out in split plot design with four replications. It comprises of four post-sowing irrigation treatments imposed for winter crops, that is only canal water (Cw); saline drainage water, $EC = 4{\cdot}6\text{–}7{\cdot}4\ dSm^{-1}$ $SAR = 14\text{–}22(mmol^{-1})^{1/2}$ (Sw); alternate use of canal water and saline drainage water (Cw-Sw); and alternate use of saline drainage water and canal water (Sw-Cw) in main plots separated by 1·5 m wide buffer borders. Five sorghum-based fodder production systems were oat-sorghum (*Avena sativa-Sorghum bicolor*), rye grass-sorghum

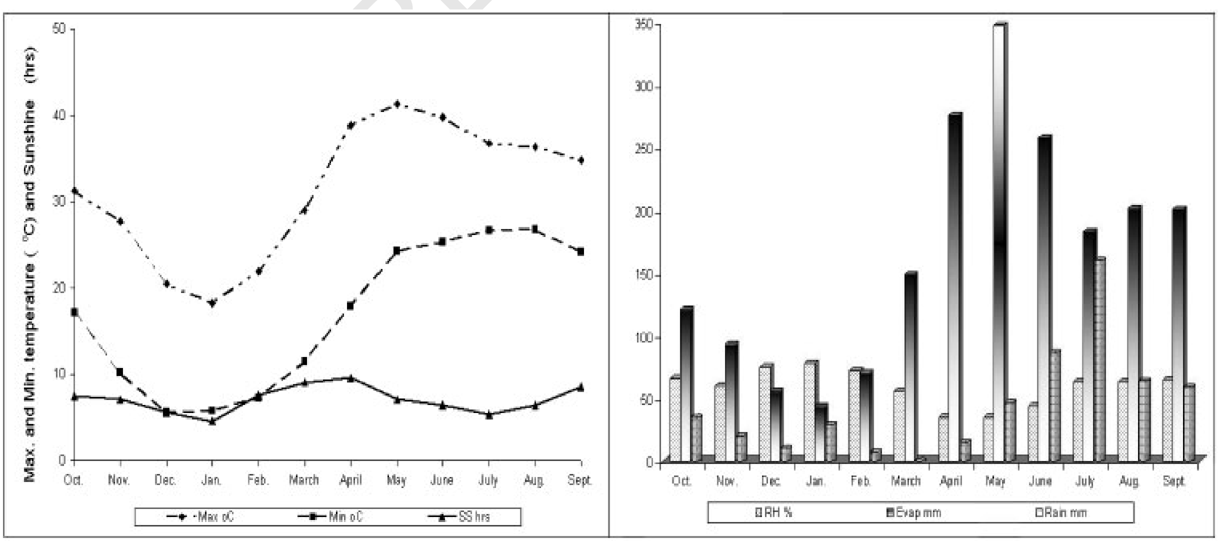

Figure 1. Weather parameters averaged for different months (1998–99) to 2001 at the site.

DOI: 10.1002/ldr

Table I. Initial physico-chemical characteristics of experimental soils

Soil depth (m)	Sand	Silt	Clay	Class	ECe (dSm^{-1})	pHs	SAR $(mmol^{-1})^{½}$	Organic C (%)	BD ($g\ cc^{-1}$)
		(%)							
0·0–0·30	70	19	10·5	LS	5·0	7·6	13	0·40	1·70
0·30–0·60	64	22	14·5	LS	5·8	7·8	14	0·34	1·59
0·60–0·90	58	25	16·0	L	6·4	8·2	16	0·26	1·52
0·90–1·20	50	26	23·4	Silt	6·7	8·0	18	0·23	1·50

(*Lolium rigidum-Sorghum bicolor*), Indian clover-sorghum (*Melilotus indica-Sorghum bicolor*), Egyptian clover–sorghum (*Trifolium alexandrinum-Sorghum bicolor)* and Persian clover-sorghum (*Trifolium resupinatum-Sorghum bicolor*) in the sub plots each measuring 20 m^2. Initial soil physico-chemical characters are shown in Table I. Good quality water (canal) had an electrical conductivity (EC) of 0·4 dSm^{-1}, pH 7·4 and sodium adsorption ratio (SAR) 0·4 $(mmol^{-1})^{½}$. The EC, pH and SAR of the drainage water used for irrigation of winter crops, changed with time with low values during winter months and high values in summer. Since, there was very little variation from year to year; the average temporal changes of EC, pH and SAR for the months of irrigation during winter crop growth period are shown in Table II.

Cultivation of Fodder Crops

Winter forage crops were sown in the second week of October in all the 3 yr using pre-sowing canal water irrigation to ensure good germination and early establishment. In every year, 9 irrigations of about 70 mm each were given to Persian clover, Egyptian clover and rye grass and seven to oat and Indian clover. Oat and Indian clover were harvested only once while four cuts were taken from Persian clover, Egyptian clover and rye grass every year. Sorghum was sown in Ist week of July in 1999 and in 2nd week of July in year 2000 and 2001. During **kharif** season, sorghum was grown as rainfed and no irrigation with saline water was applied. The recommended fertiliser rates of N and P were applied at sowing to Egyptian clover, Persian clover and Indian clover, whereas 1/3 N and full dose of P was given to oat, rye grass and sorghum at sowing and remaining 2/3 N in two equal splits at 60 and 90 days after sowing in rye grass and oat; and at 30 and 60 days after sowing in sorghum.

Analytical Procedures

Soil samples from 0·0–0·30, 0·30–0·60, 0·60–0·90 and 0·90–1·20 m were collected every year before sowing (October) and at harvesting (May) of winter crops using 50-mm diameter auger and analysed using standard methods as described by Page *et al.* (1982). Infiltration rate of soil was measured by standard single ring infiltration method (Dastane, 1972). The amount of water dispersible clay was measured on 20 g soil (0·0–0·30 m depth) from each treatment at sowing and harvest of winter crops every year in October and May respectively after making it salt free and adding distilled water so as to make total volume 1 L.

The contents were shaken well end over end. The clay content was measured by pipette method (Klute, 1986). However, total clay was determined initially using all dispersion reagents. The EC, pH and SAR of the water were

Table II. Average temporal changes in conductivity (dSm^{-1}), reaction and SAR $(mmol^{-1})^{½}$ of saline water used for irrigation of winter crops

	October	November	December	January	February	March	April	May
EC	4·9	4·6	5·1	5·4	6·3	7·2	7·6	7·5
pH	7·6	7·4	7·4	7·7	8·1	8·2	8·2	8·4
SAR	16·1	14·7	15·8	18·1	19·3	20·4	21·6	22·3

DOI: 10.1002/ldr

determined by the procedures as described in Richards (1994). Plant samples for chemical analysis were collected at harvest (in the case of Persian clover, Egyptian clover and rye grass during the third cut) and dried in oven at 70 ± 2°C for 48 hr. The dried samples were ground and sieved through 1 mm sieve. Proximate parameters like crude protein, crude fibre and tannins were determined every year following the standard procedures (AOAC; 1990). These samples were also analysed for contents of Na^+, K^+, and Na^+:K^+ ratio after digestion with diacid and other procedures each year as described by Bhargava and Raghupathi (1993). The 3 yr results were averaged and compared statistically.

RESULTS AND DISCUSSION

Green Fodder and Dry Matter Yield

Over all green fodder and dry matter yields obtained with different modes of conjunctive use of saline and good quality water were in order Cw > Cw-Sw > Sw-Cw > Sw (Table III and IV). The average green yield reductions in **Rabi** crops with Cw-Sw, Sw-Cw and Sw compared to canal water use throughout season were 14, 33 and 40 per cent respectively (Table III). Severe adverse impact of poor quality water use was observed on fodder yield of winter crops with reduced extent on sorghum grown during **Kharif**. Green fodder yield reductions compared with Cw in rye grass, oat, Persian clover, Egyptian clover and Indian clover during winter and sorghum in **Kharif** due to irrigations with saline water during winter were 36, 42, 54, 68, 85 and 26 per cent respectively indicating more deleterious effect on leguminous fodders of winter season and lower on sorghum grown during **Kharif** as rainfed crop.

Among winter crops rye grass and oat were least sensitive while Indian clover was most sensitive to salt load as a consequence of saline water irrigations. The decrease in green fodder and dry matter yield of different crops depends upon several factors such as inherent tolerance of a crop to saline environment, soil type, climate, crop water requirement and stage of crop growth at which it was exposed to hostile environment. About 50 per cent higher green fodder yield of winter crops was obtained in treatment Cw-Sw in comparison to Sw-Cw (Table III), because in the former crops were exposed to salt stress at comparatively advanced stage than in later one. Both these cyclic modes of conjunctive use of saline and good quality water proved better over continuous use of saline water throughout season. The differences in production of different crops with distinct modes of conjunctive use of saline and canal water could be due to their yield potential and tolerance to saline environment as recorded earlier by Mass and Hoffman (1977) and Troug and Roberts (1992).

Chemical Composition and Proximate Quality

The contents of Na^+ increased appreciably while slight decrease in K^+ content of fodders had been observed with the use of higher quantity of poor quality water under conjunctive use of saline water with good water (Table VI).

Table III. Three year average green fodder yield (t ha^{-1}) of different crop rotations with conjunctive use of canal and saline water

Treatments	Cw	Cw-Sw	Sw-Cw	Sw	Mean
Oat-Sorghum	34·7–29·3	32·5–26·5	24·9–22·3	22·1–23·8	28·5–25·5
E. Clover-Sorghum	37·8–34·5	30·7–28·4	17·1–23·8	12·3–22·5	24·5–27·3
P. Clover-Sorghum	38·3–32·2	33·6–30·1	25·6–24·7	17·8–21·5	28·8–27·1
I. Clover-Sorghum	21·8–30·6	12·8–25·8	8·8–21·5	3·3–24·0	11·7–25·5
Rye grass-Sorghum	36·8–26·7	34·3–24·7	27·3–20·1	23·4–22·4	30·5–23·5
Mean	33·9–30·7	28·8–27·1	20·7–22·5	15·8–22·8	
CD (5%)	Irrigation	Crops	Irrigation × Crops		
Winter	1·3	0·7	1·5		
Summer	2·1	1·5	2·8		

DOI: 10.1002/ldr

Table IV. Average (3 yr) dry matter yield (t ha^{-1}) of different rotations under conjunctive use of canal and saline water

Treatments	Cw	Cw-Sw	Sw-Cw	Sw	Mean
Oat-Sorghum	7·0–8·0	7·1–7·1	5·8–6·2	5·2–6·8	6·3–7·0
E. Clover-Sorghum	5·5–8·5	4·9–7·5	2·9–6·6	2·1–6·5	3·9–7·3
P. Clover-Sorghum	5·0–7·3	4·7–7·4	3·7–6·7	2·8–6·2	4·1–6·9
I. Clover-Sorghum	3·6–7·0	2·3–6·3	1·6–5·9	0·6–6·9	2·0–6·5
Rye grass-Sorghum	8·1–7·4	8·0–6·3	6·4–5·7	5·8–6·8	7·1–6·6
Mean	5·8–7·6	5·4–6·9	4·1–7·5	3·3–6·6	
CD (5%)	Irrigation	Crops	Irrigation × Crops		
Winter	0·4	0·2	0·4		
Summer	1·3	0·9	1·8		

The 3 yr mean contents of Na^+, revealed that leguminous fodders accumulated higher Na^+ than grassy fodders, indicating poor genetic character of Na^+ exclusion in legumes. Among crops, Indian clover and Egyptian clover had higher contents of both Na^+ and K^+ but their Na^+ accumulation as a consequence of more application of saline water had also been proportionately higher than K^+, resulting in wider Na^+:K^+ ratio than other crops. The Na^+:K^+ ratio with use of good quality water alone as compared to poor quality water increased sharply in leguminous crops, that is from 0·14 to 0·56 (4 times) in Indian clover, followed by 0·33 to 0·50 (1· 7 times) in Egyptian and Persian clovers against around only 1·2 times in rye grass, oat and sorghum. The ability of crop species to exclude salt particularly Na^+ observed earlier by Gill and Qadir (1998) as an important mechanism of salt tolerance was also evident in present study.

The proximate quality parameters like protein, crude fibre and tannins indicated that leguminous species were better quality fodders as they contained higher protein and lower contents of crude fibre and tannins in comparison to grassy species (Table V). In general, protein content decreased, crude fibre increased while tannins were not

Table V. Proximate quality (average of 3 yr) of different crops with conjunctive use of saline and good quality water

Treatments	Cw	Cw-Sw	Sw-Cw	Sw	Mean
Protein (%)					
Oat-Sorghum	11·0–9·8	10·5–10·0	9·6–9·7	9·4–9·3	10·1–9·7
E. Clover-Sorghum	13·4–9·8	12·9–10·4	12·0–10·0	11·4–9·6	12·4–10·0
P. Clover-Sorghum	12·1–10·1	12·0–10·6	11·0–9·8	10·9–9·6	11·5–10·2
I. Clover-Sorghum	14·2–9·5	13·8–9·7	12·8–9·4	12·4–9·8	13·3–9·6
Rye grass-Sorghum	8·7–9·2	8·7–9·5	8·4–9·0	8·4–9·6	8·6–9·3
Mean	11·9–9·7	11·6–10·0	10·8–9·6	10·5–9·4	
Crude fibre (%)					
Oat-Sorghum	22·1–25·8	21·5–26·2	24·0–26·7	25·4–27·3	23·2–26·5
E. Clover-Sorghum	18·0–23·7	18·4–25·4	20·3–25·0	21·1–26·1	19·5–25·1
P. Clover-Sorghum	19·4–24·2	19·5–25·5	20·7–25·3	21·9–26·5	20·4–25·4
I. Clover-Sorghum	19·7–25·0	19·5–24·9	21·4–26·3	21·6–26·0	20·6–25·6
Rye grass-Sorghum	24·8–24·4	25·2–25·7	26·3–24·9	27·1–25·6	25·8–25·2
Mean	20·8–24·6	20·8–25·5	22·5–25·6	23·4–26·3	
Tannins (%)					
Oat-Sorghum	0·30–0·34	0·31–0·34	0·29–0·31	0·31–0·32	0·30–0·33
E. Clover-Sorghum	0·20–0·31	0·20–0·36	0·21–0·29	0·22–0·34	0·21–0·32
P. Clover-Sorghum	0·34–0·32	0·32–0·35	0·31–0·33	0·31–0·28	0·32–0·32
I. Clover-Sorghum	0·14–0·35	0·14–0·31	0·13–0·27	0·13–0·34	0·14–0·31
Rye grass-Sorghum	0·40–0·33	0·37–0·32	0·36–0·32	0·38–0·31	0·38–0·32
Mean	0·28–0·32	0·27–0·34	0·26–0·30	0·27–0·321	

DOI: 10.1002/ldr

Table VI. Contents of Na^+, K^+ and their ratio in forage crops under conjunctive use of saline and good quality water

Treatments	Cw	Cw-Sw	Sw-Cw	Sw	Mean
Na (%)					
Oat-Sorghum	0·35–0·43	0·44–0·38	0·47–0·46	0·51–0·49	0·44–0·44
E. Clover-Sorghum	1·05–0·37	1·23–0·42	1·37–0·51	1·46–0·46	1·28–0·44
P. Clover-Sorghum	1·12–0·40	1·16–0·43	1·24–0·45	1·29–0·47	1·20–0·43
I. Clover-Sorghum	0·76–0·38	1·25–0·40	1·49–0·47	1·58–0·46	1·27–0·43
Rye grass-Sorghum	0·40–0·43	0·42–0·42	0·43–0·45	0·46–0·51	0·43–0·45
Mean	0·74–0·40	0·90–0·41	0·99–0·47	1·06–0·48	
K (%)					
Oat-Sorghum	1·31–1·46	1·36–1·52	1·29–1·40	1·26–1·38	1·31–1·43
E. Clover-Sorghum	3·23–1·29	3·06–1·42	3·11–1·37	2·91–1·45	3·08–1·38
P. Clover-Sorghum	3·08–1·36	3·12–1·28	2·86–1·34	2·88–1·48	2·98–1·36
I. Clover-Sorghum	3·31–1·42	3·05–1·50	2·79–1·43	2·84–1·40	3·00–1·44
Rye grass-Sorghum	1·19–1·35	1·26–1·38	1·12–1·46	1·20–1·44	1·19–1·41
Mean	2·42–1·38	2·37–1·42	2·24–1·40	2·21–1·43	
Na:K ratio					
Oat-Sorghum	0·27–0·29	0·32–0·25	0·36–0·33	0·41–0·36	0·34–0·31
E. Clover-Sorghum	0·33–0·29	0·40–0·30	0·44–0·37	0·50–0·32	0·42–0·32
P. Clover-Sorghum	0·36–0·29	0·37–0·34	0·43–0·34	0·45–0·32	0·40–0·32
I. Clover-Sorghum	0·14–0·27	0·41–0·27	0·54–0·33	0·56–0·33	0·41–0·30
Ryegrass-Sorghum	0·34–0·32	0·33–0·30	0·38–0·31	0·38–0·35	0·38–0·32
Mean	0·29–0·29	0·37–0·29	0·43–0·34	0·46–0·34	

affected with use of increasing amounts of poor quality water under different modes of conjunctive use of good and saline water. The adverse impact of saline water use on chemical composition and proximate quality had been low with alternate use of good and saline water (Cw-Sw) in comparison to cyclic use started with saline water (Sw-Cw) and saline water use alone (Sw) throughout the season. The decreased protein content with poor quality water use could be due to higher losses of nitrogen as a consequence of volatilisation under alkaline effect of high SAR saline water leading to lower availability to crops and hence low formation of amino acids, the precursors of proteins. Bajwa and Singh (1992) recommended 25 per cent higher N application under sodic conditions to compensate for volatilisation losses. The higher synthesis of structural carbohydrates under stress conditions and later stages as recorded by Panwar *et al*. (1999) might be the reason for increased crude fibre content with application of higher amounts of poor quality water.

Soil Salinity (Conductivity) and Reaction

Soil samples drawn at sowing and harvest of winter crops from different depths revealed that soil conductivity had increased with application of increased amounts of saline water and its prolonged use. However, the adverse impact was more in upper layers as compared to lower depths during harvest of winter season crops. This was due to accumulation of salts as a consequence of application of more numbers of irrigations (3) in treatment Cw-Sw to 7/9 irrigations of saline water every year in Sw and higher evaporation rates during summers. The leaching of salts during monsoon and applications of pre-sowing irrigation with good quality water resulted in lower salinity in soil profile at sowing of winter crops during October in respective years. There has been very low impact of crops on salinity build up and hence, the soil salinity with different cyclic modes of conjunctive use in all crops were aggregated, averaged and presented. The surface (0·30 m) soil salinity had increased from 5·0 dSm^{-1} in beginning during October 1998 to 8·3 dSm^{-1} in May, 2001 under good quality water use alone throughout season as compared to 12·2 dSm^{-1} under saline water use throughout season (Figure 2). When the surface soil salinity levels of October 1998 and October 2000 were compared, then it was noticed that there had not been any apparent salt build up with good quality water use alone (Cw) in comparison to 15 per cent build up with poor quality water (Sw) application

DOI: 10.1002/ldr

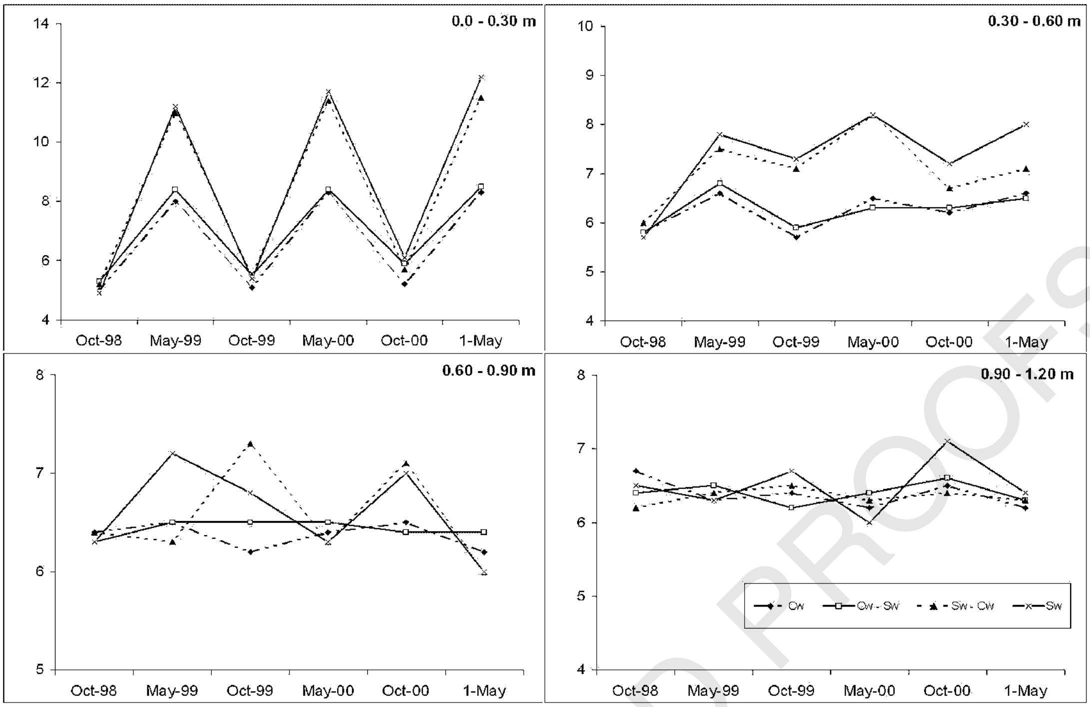

Figure 2. Periodic changes in soil salinity (dSm^{-1}) at different soil layers.

throughout season. Manchanda and Chawla (1981) also observed low salt build up at sowing and higher at harvest of wheat crop irrigated with saline water on loamy sand soils of Rewari and Gurgaon in Haryana. No apparent change in soil reaction (pH) at different soil depths was observed under different conjunctive modes of cyclic use of saline and canal water for irrigating various crop rotations.

Sodium Adsorption Ratio (SAR)

The periodic changes in SAR of soil irrigated with different cyclic modes of good and saline water (Figure 3) indicated that application of higher quantity of saline water with SAR increased surface soil SAR. Moreover, due to more labile/mobile nature of sodium salts, these were readily redistributed in the profile due to leaching with irrigation/rainfall during monsoon and evaporation during summers, resulting in increased surface (0–0·30 m) SAR values (18–19) during summer as compared to 14–16 $(mmol^{-1})^{1/2}$ during October at the time of sowing of winter crops. There were very little changes in sub-surface SAR values.

Infiltration Rate and Clay Dispersion

The evaluation of continuous use of poor quality water on permeability and clay dispersion was considered important because this could result in structural deterioration of soils. The infiltration rates recorded at different times indicated that application of good and saline water in different cyclic modes did not affect the infiltration rate of soil appreciably. However, there had been slight decrease in infiltration rate with saline water use throughout the season from 4·3 cm day^{-1} in the beginning to 4·1 cm day^{-1} at the harvest of winter crops in May, 2001 (Table VII). At this rate of infiltration approximately 35 hr would be required to infiltrate 6·5 cm irrigation water, which would not affect leguminous crops severely but further deterioration in infiltration rate could be harmful.

DOI: 10.1002/ldr

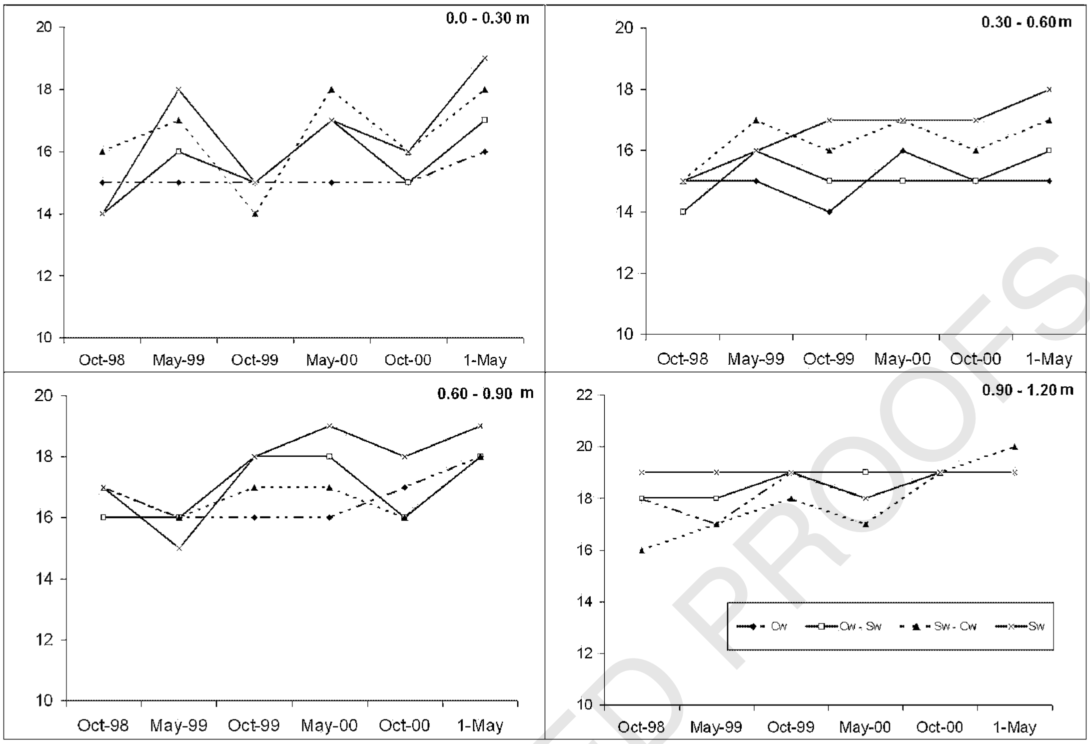

Figure 3. Periodic changes in sodium adsorption ration: SAR $(mmol^{-1})^{1/2}$ at different soil layers.

When water dispersible clay was measured, it was found that there had been slight increase in this parameter with application of increasing amounts of saline-SAR water. No apparent change in water dispersible clay was observed under good quality water use but the increase in water dispersible clay content of surface soils as recorded in May, 2001 with poor quality water application had been 14, 16 and 19 per cent respectively under alternate use of canal and saline water (Cw-Sw), alternate use of saline and canal water (Sw-Cw) and drainage water use alone (Sw)

Table VII. Infiltration rate and water dispersible clay contents of soil with conjunctive use of saline and good quality water

	October 1998	May 1999	October 1999	May 2000	October 2000	May 2001
Infiltration rate (cm day^{-1})						
Cw	4·4	4·5	4·4	4·3	4·2	4·4
Cw-Sw	4·5	4·2	4·6	4·4	4·4	4·2
Sw-Cw	4·3	4·1	4·3	4·1	4·3	4·2
Sw	4·3	4·2	4·4	4·3	4·2	4·1
CD at 5%	NS	NS	NS	NS	NS	NS
Water dispersible clay contents (%)						
Cw	2·68	2·54	2·61	2·65	2·63	2·59
Cw-Sw	2·49	2·69	2·74	2·71	2·77	2·84
Sw-Cw	2·52	2·76	2·73	2·76	2·85	2·92
Sw	2·56	2·73	2·76	2·82	2·89	3·04
Mean	2·56	2·68	2·70	2·74	2·79	2·85
CD at 5%	NS	NS	NS	NS	0·14	0·19

DOI: 10.1002/ldr

throughout seasons over initial 2·56 per cent (Table VII). These results suggested restrictions on the continuous use of such poor quality water even on these loamy sand saline soils. However, the extent of deterioration could be reduced by adopting cyclic mode of conjunctive use of saline and good quality water. Minhas and Sharma (1986) observed reduced permeability with clay dispersion more than 57 per cent thereby reducing relative hydraulic conductivity beyond critical limit of 0·75 in mixed layer chlorite/illitic sandy loam soils. Though such relationship was not established in present study but minute adverse impact on infiltration rates have been recorded with increased clay dispersion.

SUMMARY

The data on fodder production, proximate quality and soil properties suggested that if crops are sown with good quality water and thereafter given alternate irrigations of canal and saline water, the adverse impacts could be minimised. Rye grass, oat, sorghum and Persian clover were comparatively more tolerant to saline conditions than Egyptian/Indian clover. The slight adverse effect on infiltration rate and water dispersible clay with continuous use of increasing quantities of marginal quality water warrants for continuous monitoring of these parameters. However, such adverse impacts on production and soil health could be minimised by using saline and good water in cyclic mode of conjunctive use.

ACKNOWLEDGEMENTS

Authors are thankful to Directors of CSSRI, Karnal, CIRB, Hisar and NBSS&LUP, Nagpur for providing necessary facilities for conducting the studies and their constructive suggestions. Indian Council of Agricultural Research-Central Soil Salinity Research Institute, Karnal, Haryana, India.

REFERENCES

AOAC. 1990. *Official Methods of Analysis*, 12th edn. Association of Analytical Chemists: Washington DC.

Bajwa MS, Singh B. 1992. Fertilizer nitrogen management for rice and wheat crops grown in alkali soils. *Fertilizer News* **37**(8): 47–59.

Bhargava BS, Raghupathi HB. 1993. Analysis of plant materials for macro and micronutrients. In Tondon HLS (ed). *Methods of Analysis of Soils Plants, Water and Fertilizers*. FEDCO: New Delhi; 49–82.

Bradford S, Letey J. 1992. Cyclic and blending strategies for using non-saline and saline waters for irrigation. *Irrigation Science* **13**: 123–128.

Dastane NG. 1972. *A Practical Manual for Water Use Research in Agriculture*. Navbharat Publication, Pune: India.

Gill KS, Qadir A. 1998. Physiology of salt tolerance. In *Agricultural Salinity Management in India*, Tyagi NK, Minhas PS (eds). CSSRI, Karnal: India; 243–258.

Klute A. 1986. *Methods of soil analysis*, Part I. ASA Monograph No. 9, Madison, WI, USA.

Manchanda HR, Chawla KL. 1981. Salt profile variations and wheat growth under irrigation with saline water on loamy soils in Haryana. *Journal of Indian Society of Soil Science* **29**(4): 504–511.

Mass EV, Hoffman GL. 1977. Crop salt tolerance-current assessment. *Journal of Irrigation and Drainage Division, ASCE* **113**(IR2): 115–134.

Minhas PS, Sharma DR. 1986. Hydraulic conductivity and clay dispersion as affected by application sequence of saline and simulated rainwater. *Irrigation Science* **7**: 159–167.

Page AL, Miller RH, Kenny DR. 1982. *Methods of Soil Analysis*. Parts I and II, American Society of Agronomy: Madison, Wisconsin.

Panwar VS, Tewatia BS, Lodhi GP. 1999. Chemical composition and dry matter digestibility of some sorghum varieties. *Forage Research* **24**: 209–211.

Richards LA. 1994. *Diagnosis and Improvement of Saline and Alkali Soils*. USDA, Handbook No.60. ???[Q2]. Q2

Singh RP, Poonia SR. 1980. Effect of water quality on water transmission parameters of unsaturated soils. *Journal of Indian Society of Soil Science* **28**(1): 1–9.

Troug PN, Roberts MH. 1992. Salt tolerance of tropical and subtropical grasses grown in Queensland. In *Proceedings National Workshop on Productive Use of Saline Land*. No. 42, ACIAR, Perth: Western Australia, 1–14 May, 36–40.

Tyagi NK, Minhas PS. 2002. *Agricultural Salinity Management in India*. CSSRI, Karnal: India; 526.

Yadav RK, Kumar A, Lal D, Batra L. 2004. Yield responses of winter (*Rabi*) forage crops to irrigation with saline drainage water. *Experimental Agriculture* **40**: 65–75.

DOI: 10.1002/ldr

Author Query Form (LDR/776)

Special Instructions: Author please write responses to queries directly on Galley proofs and then fax back.

Q1: Author: Please check the affiliation of the author.

Q2: Author: Please provide publisher and its location.