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Effect of micro-irrigation methods on the performance of peanut genotypes irrigated with alkali water

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ABSTRACT

Peanut is one of the most important oilseed crops of India. It is mostly grown in *kharif* season, although it performs very well during summer. Because of high potentiality and productivity, the summer yield is almost two times higher as compared to *kharif* cultivation. Water as one of the major input in crop production is increasingly becoming scarce and costly day by day. Therefore, its judicious use is very much essential for achieving higher water use efficiency. Micro-irrigation systems are considered to be the most efficient as compared to the surface methods of irrigation and by adopting them; considerable amount of water can be saved with increased production. Information on micro-irrigation system for summer peanut is scarce. Therefore, a field experiment was conducted at Anbil Dharmalingam Agricultural College and Research Institute, Tiruchirapalli during 2011 to study the micro-irrigation methods on peanut productivity using alkali water. The experiment was laid-out with Factorial Randomized Block Design. Four micro-irrigation methods viz., drip, micro-sprinkler, sprinkler and rain gun and nine peanut genotypes viz., TMV 2, TMV 7, TMV 10, TMV 13, VRI2, VRI 3, VRI 4, VRI 5, and VRI 7 were used for the experiment. Among the micro-irrigation methods, drip irrigation and micro-sprinkler irrigation are superior over other two methods for all the peanut genotypes. Higher water use efficiency of 31.44 kg/ha-cm was recorded in drip irrigation followed by micro-sprinkler irrigation (26.59 kg/ha-cm). Under drip irrigation method, peanut genotypes viz., TMV 7, TMV 13, and VRI 7 and under micro-sprinkler irrigation method, genotypes viz., VRI 7, TMV 13 and VRI 2 recorded significantly higher yield than the other genotypes. Among different peanut genotypes, TMV 13 and VRI 7 recorded higher yield under all four micro-irrigation methods. Drip irrigation recorded higher yield and water use efficiency followed by micro-sprinkler irrigation method as compared to other methods.

Key words: alkali water, drip irrigation, micro-irrigation, peanut, raingun, sprinkler

Introduction

Peanut is one of the most important oil seed crops of India and is mostly grown in summer season. Water is the vital source for crop production and is becoming scarce year after year. The average rainfall of Tamil Nadu is 958.5 mm (India Meteorological Department, 2008) as against the average rainfall of 1200mm (The Pulse of Indian Agriculture, 2008) in the country. India's crop production suffers mainly from the availability of water. Thus, water is the most limiting factor in the Indian agricultural scenario. Further, the unscientific use of available irrigation water compounds the problem in crop production. It is becoming increasingly clear that with the advent of the high yielding varieties, the next major advance in our agricultural production is expected to come only through efficient water management practices. Surface irrigation systems are less efficient in applying water than pressurized or micro-irrigation systems. Considerable amount of irrigation water could be saved with the use of micro-irrigation systems with increased production. Poor quality waters can also be used with micro-irrigation systems. In India, the potential for the micro-irrigation system is more than 21.27 m ha (Narayanamoorthy, 2008). The water use efficiency can be maximized with the use of micro-irrigation methods. The objective of this research was to study the effect of different micro-irrigation methods on peanut productivity using alkali water.

Material and Methods

Field experiment was conducted at Anbil Dharmalingam Agricultural College and Research Institute, Trichy, Tamil Nadu during 2011 to study the influence of micro-irrigation methods on peanut productivity using alkali water. The field is located at 10^{o} 45' N latitude and 78^{o} 36' E longitude at an altitude of 85 m above mean sea level. The average annual rainfall of the location is 926 mm. The soil of the experimental area was non saline calcareous sodic soil and it belongs to fine, calcareous isohyperthemic family of Vertic Ustropept

Table 1. Quality of irrigation water

Particulars	Value
pH	9.0
EC (dS m^{-1})	1.65
Ca (me L^{-1})	7.2
Mg (me L^{-1})	6.0
RSC (me L^{-1})	7.8
SAR ($mmol^{1/2}$ $L^{-1/2}$)	10.7

texture. The water is alkali in nature. The quality of irrigation water is given in Table 1.

The experiment was laid out in a Factorial Randomized Block Design with two factors: 1. Four micro-irrigation methods viz., drip, micro-sprinkler, sprinkler and raingun and 2. Nine peanut genotypes viz. TMV 2, TMV 7, TMV 10, TMV 13, VRI 2, VRI 3, VRI 4, VRI 5 and VRI 7. The daily pan evaporation data was used for scheduling the irrigation and irrigations were given at three days interval in drip irrigation and micro-sprinkler irrigation, and at 6 days interval in sprinkler and rain gun irrigation. The details of micro-irrigation methods are as follows.

(a) Drip irrigation

Lateral spacing	:	1.5 m
Dripper spacing	:	0.60 m
Operating pressure	:	1-1.5 kg / cm^2
Dripper discharge	:	4 lph
Depth of irrigation per hour of operation	:	4.445 mm / hr

(b) Micro-sprinkler irrigation

Wetting diameter	:	3 m
Discharge	:	35 lph
Overlapping	:	50%
Spacing of micro-sprinklers	:	1.5 m
Operating pressure	:	1.5 – 2.0 kg / cm^2
Depth of irrigation per hour of operation	:	9.89 mm/ hr

(c) Sprinkler irrigation

Operating pressure	:	3.5 kg / cm^2
Discharge	:	2000 lph
Wetting diameter	:	15 m
Spacing of sprinklers	:	9 m
Depth of irrigation per hour of operation	:	22.6 mm / hr

(d) Raingun irrigation

Operating pressure	:	5-7 kg / cm^2
Wetting diameter	:	25 m
Discharge	:	5 lps
Depth of irrigation per hour of Operation	:	36.65 mm / hr.

The crop was shown on 01.03.2011 and harvested on 25.06.2011.

Results and discussion

Biometric observations on plant height, number of branches per plant, number of pods per plant and weight of pods per m^2 recorded at the time of harvest are furnished in Table 2. The data on biometric observation of different peanut genotypes under various micro-irrigation methods revealed that drip irrigation and micro-sprinkler irrigation are superior over other two methods for almost all the peanut genotypes. Drip irrigation method recorded higher yields in TMV 7 (1596 kg ha^{-1}) followed by TMV 13 (1584 kg ha^{-1}) and VRI 7 (1554 kg/ ha) whereas micro-sprinkler irrigation method recorded higher yields in VRI 7 (1542 kg ha^{-1}) followed by TMV 13 (1512 kg ha^{-1}). The yields obtained in sprinkler and raingun methods of irrigation were inferior compared to drip method of irrigation in all the peanut genotypes tested. Comparing the performance of groundnut genotypes in various micro-irrigation methods, the plant height, number of branches, number of pods per plant were the highest in drip irrigation method followed by micro-sprinkler, sprinkler and raingun. Similar results of increase in plant height, other biometric parameters and yield were reported for several crops (Selvaraj, 1997; Aruna Devi, 2005) in drip irrigation method.

Water use efficiency (WUE)

The influence of various micro-irrigation methods and the performance of different peanut genotypes using alkali water on water use efficiency are furnished in Table 3. The total water used was worked out by adding irrigation water applied and effective rainfall during the crop growing season. The total water used was 45.98 cm, 52.40 cm, 55.35 cm and 57.87 cm respectively in drip, micro-sprinkler, sprinkler and rain gun irrigation methods. Maximum water use efficiency of 34.71 kg/ha-cm was recorded in drip irrigation method with TMV 7 genotype followed by TMV 13 (34.45 kg/ha-cm) and VRI 7 (33.80 kg/ha-cm) in drip irrigation method. In micro-sprinkler irrigation method, maximum water use efficiency of 29.43 kg /ha-cm was obtained with VRI 7 genotype followed by TMV 13 (28.86 kg/ha-cm). In sprinkler and rain gun irrigation methods, the water use efficiencies were less compared to the drip and micro-sprinkler irrigation methods.

Table 2. Influence of micro-irrigation methods on biometric observations and yield of peanut genotypes.

Irrigation / variety	Plant height (cm)	No. of branches per plant	No. of pods per plant	Wet weight of pods / m^2 (g)	Dry weight of Pods (g/m^2)	Pod Yield (kg / ha)
			Drip Irrigation			
TMV 2	39.2	6.6	16.1	251	150.6	1506
TMV 7	45.1	7.3	19.2	266	159.6	1596
TMV 10	44.0	8.5	18.7	242	145.2	1452
TMV 13	39.2	8.7	15.8	264	158.4	1584
VRI 2	48.0	8.2	15.0	243	145.8	1458
VRI 3	46.9	7.5	16.1	235	141.0	1410
VRI 4	45.4	7.8	14.5	239	153.4	1534
VRI 5	45.1	8.6	13.7	246	147.6	1476
VRI 7	49.7	8.5	15.3	259	155.4	1554
			Micro-Sprinkler Irrigation			
TMV 2	45.6	6.9	13.8	234	140.4	1404
TMV 7	42.1	7.3	15.4	235	141.0	1410
TMV 10	39.0	7.7	15.9	240	144.0	1440
TMV 13	45.0	8.0	15.6	252	151.2	1512
VRI 2	49.6	7.9	13.8	244	146.4	1464
VRI 3	39.8	7.4	13.9	235	141.0	1410
VRI 4	40.1	7.5	14.2	233	139.8	1398
VRI 5	41.2	8.0	13.1	230	138.0	1380
VRI 7	42.3	8.2	14.6	257	154.2	1542
			Sprinkler Irrigation			
TMV 2	36.8	6.6	11.8	201	120.6	1206
TMV 7	39.6	6.8	12.4	208	124.8	1248
TMV 10	38.6	6.9	12.5	204	122.4	1224
TMV 13	34.4	7.2	12.8	212	127.2	1272
VRI 2	41.2	6.9	11.6	195	117.0	1170
VRI 3	38.6	7.1	12.1	203	121.8	1218
VRI 4	34.4	6.8	12.2	209	125.4	1254
VRI 5	39.2	7.1	11.8	198	118.8	1188
VRI 7	39.8	7.3	12.4	218	130.8	1308
			Raingun Irrigation			
TMV 2	35.4	6.4	12.0	207	124.2	1242
TMV 7	38.9	6.5	11.9	204	122.4	1224
TMV 10	37.6	6.7	12.1	210	126.0	1260
TMV 13	34.1	7.1	12.4	217	130.2	1302
VRI 2	38.8	6.8	12.2	191	114.6	1146
VRI 3	36.7	6.9	11.8	198	118.8	1188
VRI 4	33.8	6.4	11.9	204	112.4	1224
VRI 5	37.9	6.6	10.8	201	120.6	1206
VRI 7	37.2	7.0	11.9	212	127.2	1272
SEd	1.19	0.04	0.09	3.48	2.09	20.9
CD (P=0.05)	**2.42**	**0.08**	**0.21**	**7.61**	**4.51**	**45.1**

Among the various micro-irrigation methods tried, drip irrigation was found superior in achieving higher water use efficiency followed by micro-sprinkler irrigation. The reason for higher water use efficiency in drip irrigation might be due to higher yield registered through application of less irrigation water. Drip irrigation recorded more (14–21per cent) water saving over other micro-irrigation methods. Among the various peanut genotypes tested, TMV 7, TMV 13 and VRI 7 recorded higher water use efficiencies with drip irrigation and the genotypes VRI 7 and TMV 13 recorded higher water use efficiencies in micro-sprinkler irrigation. Hence, the peanut genotypes VRI 7 and TMV 13 are well suited to alkali water irrigation with drip and micro-sprinkler irrigation

Table 3. Water use details and water use efficiency

Irrigation / Variety	Irrigation water applied (cm)	Effective rainfall (cm)	Total water used (cm)	Yield (kg/ ha)	WUE (kg / ha. cm)
			Drip Irrigation		
TMV 2	41.25	4.73	45.98	1506	32.75
TMV 7	41.25	4.73	45.98	1596	34.71
TMV 10	41.25	4.73	45.98	1452	31.58
TMV 13	41.25	4.73	45.98	1584	34.45
VRI 2	41.25	4.73	45.98	1458	31.71
VRI 3	41.25	4.73	45.98	1410	30.67
VRI 4	41.25	4.73	45.98	1534	33.36
VRI 5	41.25	4.73	45.98	1476	32.10
VRI 7	41.25	4.73	45.98	1554	33.80
			Micro-Sprinkler Irrigation		
TMV 2	47.67	4.73	52.40	1404	26.78
TMV 7	47.67	4.73	52.40	1410	26.91
TMV 10	47.67	4.73	52.40	1440	27.48
TMV 13	47.67	4.73	52.40	1512	28.86
VRI 2	47.67	4.73	52.40	1464	27.93
VRI 3	47.67	4.73	52.40	1410	26.90
VRI 4	47.67	4.73	52.40	1398	26.68
VRI 5	47.67	4.73	52.40	1380	26.34
VRI 7	47.67	4.73	52.40	1542	29.43
			Sprinkler Irrigation		
TMV 2	50.62	4.73	55.35	1206	21.79
TMV 7	50.62	4.73	55.35	1248	22.54
TMV 10	50.62	4.73	55.35	1224	22.11
TMV 13	50.62	4.73	55.35	1272	22.98
VRI 2	50.62	4.73	55.35	1170	21.13
VRI 3	50.62	4.73	55.35	1218	22.01
VRI 4	50.62	4.73	55.35	1254	22.66
VRI 5	50.62	4.73	55.35	1188	21.46
VRI 7	50.62	4.73	55.35	1308	23.63
			Raingun Irrigation		
TMV 2	53.14	4.73	57.87	1242	21.46
TMV 7	53.14	4.73	57.87	1224	21.15
TMV 10	53.14	4.73	57.87	1260	20.84
TMV 13	53.14	4.73	57.87	1302	22.50
VRI 2	53.14	4.73	57.87	1146	19.80
VRI 3	53.14	4.73	57.87	1188	20.53
VRI 4	53.14	4.73	57.87	1224	21.15
VRI 5	53.14	4.73	57.87	1206	20.84
VRI 7	53.14	4.73	57.87	1272	21.98

methods. Among micro-irrigation methods, drip irrigation and micro-sprinkler irrigation are superior over other two methods. Similar findings of increased water use efficiency and water saving with drip irrigation were reported by many researchers in various crops in comparison with other irrigation methods (Ramesh *et. al.,* 1994; Pawar *et. al*., 1993; Hodgson *et. al*., 1990; Anon 1996; Anon. 1995).

Conclusion

The results of the present study revealed that the various micro-irrigation methods had a pronounced effect on yield and yield attributes of various peanut genotypes irrigated with alkali water. Drip irrigation was found to be superior in increasing the yield and water use efficiency of peanut genotypes followed by micro-sprinkler irrigation. The groundnut genotypes TMV 7, TMV 13 and VRI 7 performed well under drip irrigation and TMV 13 and VRI 7 performed well under micro-sprinkler irrigation. The other two micro-irrigation methods sprinkler and raingun irrigation failed to produce higher yield and WUE with alkali water and with various peanut genotypes.

References

Arunadevi, K. 2005. Performance evaluation of drip irrigation and fertigation on the yield and water use efficiency of mulberry. PhD Thesis, unpublished Tamil Nadu Agricultural University, Coimbatore.

Narayanamoorthy, A., 2008. Drip irrigation in India: can it solve water scarcity? Water Policy **6**: 117-130.

Selvaraj, P.K. 1997. Optimization of irrigation scheduling and nitrogen fertigation for maximizing water use efficiency of turmeric in drip irrigation. PhD Thesis, unpublished, Tamil Nadu Agricultural University, Coimbatore.

Ramesh, P., Kailasam and Srinivasan, T.R. 1994. Performance of sugarcane (*Saccharum officinarum L*) under surface drip subsurface drip (Biwall) and furrow methods of irrigation. *Journal of Agronomy and Crops Science* **172**: 327 – 241.

Pawar, V.S., Maher, D.P., Dahiwalker, S.D. and Bhoite, S.U. 1993. Liquid fertilizer effect through drip irrigation on yield and water use efficiency of garlic (*Allium sativum L) Journal of Water Management* **1**(1): 10-12.

Hodgson, A.S., G.A. Constable, G.R. Duddy and I.G. Faniells. 1990. A comparison of drip and furrow irrigated cotton on a crackling clay soil – water use efficiency, water logging, root distribution and soil structure. *Irrigation Science* **11**: 143-148.

Anonymous. 1996. Effect of irrigation schedules and nitrogen levels in banana and sugarcane through drip method of irrigation. Annual Report. ARS, Bhavanisagar, Tamil Nadu. 1995-1996.

Anonymous. 1995. Evaluation of micro-irrigation systems for cabbage and sapota. Annual Report. Plasticulture Development Centre, Bangalore, June 1995.

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Assessment of the groundwater quality for domestic and agricultural purposes of Malaprabha and Ghataprabha command areas in Northern Karnataka

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ABSTRACT

Analysis of groundwater samples for water quality in Malaprabha and Ghataprabha command areas in Northern Karnataka revealed that 19 per cent of the villages had poor quality groundwaters for irrigation purpose and 43.8 per cent of the villages had fluoride content above the permissible limit of 1.5 ppm. The highest percentage of villages having poor quality groundwaters for irrigation was recorded in Ron taluka in Malaprabha command area and Athani taluka in Ghataprabha command area. Regarding drinking water, about 91.7 per cent of the villages in Bailhongal taluka and 81.5 per cent of the villages in Saundatti taluka were found to have fluoride content above permissible limit. Similarly, about 36.4 percentage of the villages in Ramdurga and 33.3 percentages of villages in Saundatti taluka of Malapraba command area had drinking water having higher NO_3 contents. Poor quality groundwaters were reported in 22.5 per cent of the samples in Malaprabha and 31.8 per cent in Ghataprabha command area and they showed different kinds of salinity problems. The water quality analytical data indicated that high SAR saline water existed in Araladhakatti, Kagadal, Jagapur, Hadli, Gadagoli in Malprabha command area and Biradi, Chinchali, Nandagoan, Maigur, Shegunasi villages in Ghataprabha command area. Saline waters were found in Asuti in Malaprabha and Kuligod, Kullali, Alagur, Muttur and Shankratti in Ghataprabha command area. Marginally saline waters occurred in about 15 villges in Malaprabha command and 26 villages in Ghataprabha commond area. Seasonal water quality characteristics in both the command areas indicated a decrease in pH and an increase in EC and other ions during summer. Contrary to this, the lower concentrations of ions studied and slightly higher pH values were recorded during the canal open periods.

***Key words*:** fluoride, nitrate, poor quality water, TDS, water quality

Introduction

Water is one of the most important inputs required for crop production. Supplementary irrigation is important in India where one-third of the land surface falls under arid and semi-arid climate and the rainfall is seasonal and erratic. Problems with water quality are often as severe as the problems of water availability. In many cases, groundwater resources have been rendered unsafe for human consumption as well as irrigation and industrial needs due to their poor quality. Malaprabha and Ghataprabha projects are boon to the farming community of North Karnataka since these two projects facilitate irrigation for the dry districts in this region. The command of Malaprabha was proposed to irrigate 2.5 lakh ha, out of which 1.61 lakh ha is actually irrigated as of now. The Ghataprabha irrigation project with a live reservoir capacity of 49 TMC is estimated to have an ultimate potential of irrigating 7.84 lakh ha. The farmers in the Malaprabha command area are getting canal water for 6-8 months. As a result, the farmers are forced to look for alternative sources of water for the intensive crop production especially during canal closure periods. Also, a study indicated that nearly 40 per cent of the net irrigated area receives water from wells and borewells in these commands. Systematic studies on the quality assessment of these two projects and ways and means for the use and management of poor quality groundwaters and their effect on soil health, salt balance and development of suitable model for better management of poor quality groundwaters are lacking. To minimize the threat of land and groundwater contamination, further studies are required to be undertaken for water quality assessment in these command areas. On this pretext, we carried out the present investigation.

Material and Methods

A total of 840 groundwater samples (302 in Malaprabha and 538 in Ghataprabha command area) were collected village-wise during the year 2005. Running tube-wells distantly apart within each village were selected randomly for the collection of water samples. The samples were collected during summer months (April/May) in capped high density PVC bottles, fortified with 1 mL toluene to arrest any biological activity. The samples were analysed for SAR and other salinity and alkalinity problems and classified as per classification. The fluoride content was determined using specific ion analyzer with F electrode (Orion). The anion nitrate was determined by using the standard methods outlined in USDA Hand book 60 (Richards, 1954).

Results and Discussion

The village-wise analysis of groundwater samples revealed that 19 per cent of the villages had poor quality groundwaters for irrigation purpose, 43.8 per cent of the villages had fluoride content more than permissible limit of 1.5 ppm and 26.8 per cent of the villages had nitrate content more than permissible limit in Malaprabha command area. The corresponding percentage values of the villages in the Ghataprabha command area for these parameters were 27, 26.3 and 35.3 per cent, respectively. The highest percentage (100%) of villages having poor quality groundwaters for irrigation was recorded in Ron taluka in Malaprabha command area and Athani taluka in Ghataprabha command area.

Regarding the suitability for drinking, about 91.7 per cent of villages in Bailhongal and 81.5 per cent villages in Saundatti taluka were found to be unsafe with respect to flouoride content and 36.4 percentage of villages in Ramdurga and 33.3 percentage of villages in Saundatti taluka were found to be unsafe with respect with to NO_3 content in Malaprabha command area (Table 1). In Ghataprabha command area, groundwaters of 50 per cent villages in Gokak taluka and 40 per cent villages in Chikkodi taluka were found to be unsafe with respect to fluoride content. Similarly, 50 per cent of the villages in Gokak taluka and 42.9 per cent of the villages in Jamkhandi taluka had nitrate contents exceeding the permissible limits (Table 2).

Summary of the individual water sample analysis revealed that the groundwaters of Malaprabha and Gataprabha command areas belonged to the categories of either good, marginally saline, saline, high SAR saline, marginally alkali or alkali waters for irrigation purpose as per CSSRI guidelines (Tables 3 & 4). Poor quality groundwaters were reported in 22.5 per cent of the samples in Malaprabha command area of which the contributions of marginally saline, marginally alkali, saline and high SAR saline were 8.6, 6.6, 2.6, 2.3 and 4.3 per cent, respectively. Our results are in agreement with Paliwal (1972) who concluded that the salinity and sodicity hazards from well waters were more in western

Table 1. Village-wise summary of the groundwater sample analysis of Malaprabha Command Area

Name of the taluka	No. of the Villages sampled	Water quality for irrigation				Water quality for drinking purpose			
		No. of villages falling under the category Good	No. of villages falling under the category Marginally saline	No. of villages falling under the category saline	No. of villages falling under the category High SAR saline	No. of villages Having fluoride content <1.5 ppm	No. of villages Having fluoride content >1.5 ppm	No. of villages Having fluoride content <50 ppm	No. of villages Having fluoride content >50 ppm
Saundatti	27	23 (85.2)	2 (7.4)	0 (0.0)	2 (7.4)	5 (18.5)	22 (81.5)	18 (65.6)	9 (33.3)
Ramdurga	44	42 (95.4)	2 (4.5)	0 (0.0)	0 (0.0)	43 (97.7)	1 (2.3)	28 (63.6)	16 (36.4)
Bailhongal	24	22 (91.7)	2 (8.3)	0 (0.0)	0 (0.0)	2 (8.3)	22 (91.7)	20 (83.3)	4 (16.7)
Navalgund	6	3 (20.0)	1 (8.0)	0 (0.0)	2 (0.0)	5 (60.0)	1 (40.0)	5 (100.0)	1 (0.0)
Naragund	6	3 (50)	1 (16.7)	0 (0.0)	2 (33.3)	5 (83.3)	1 (16.7)	5 (83.3)	1 (16.7)
Ron	6	0 (0.0)	4 (66.7)	1 (16.7)	1 (16.7)	5 (83.3)	1 (16.7)	6 (100.0)	0 (0.0)
Total	112	91 (81.25)	15 (13.4)	1 (0.9)	5 (4.5)	63 (56.2)	49 (43.8)	82 (73.2)	30 (26.8)

Values in parentheses indicate percentage of villages falling under a particular category over total number of villages coming under a particular taluka

Table 2. Village-wise summary of the groundwater sample analysis of Ghataprabha Command Area

Name of the taluka	No. of the Villages sampled	Water quality for irrigation				Water quality for drinking purpose			
		No. of villages falling under the category Good	No. of villages falling under the category Marginally saline	No. of villages falling under the category saline	No. of villages falling under the category High SAR saline	No. of villages Having fluoride content <1.5 ppm	No. of villages Having fluoride content >1.5 ppm	No. of villages Having fluoride content <50 ppm	No. of villages Having fluoride content >50 ppm
Gokak	26	23 (88.5)	2 (7.6)	1 (3.8)	0 (0.0)	13 (50.0)	13 (50.0)	13 (50.0)	13 (50.0)
Raibhag	32	425 (78.1)	4 (12.5)	1 (3.1)	2 (6.2)	30 (93.8)	2 (6.2)	22 (68.8)	10 (31.2)
Chikkodi	10	6 (60.0)	4 (40)	0 (0.0)	0 (0.0)	6 (60.0)	4 (40.0)	8 (80.0)	2 (20.0)
Athani	6	0 (0.0)	4 (66.7)	1 (16.7)	1 (16.7)	6 (100.0)	0 (0.0)	4 (66.7)	2 (33.3)
Jamkhandi	28	19 (67.8)	5 (17.8)	3 (10.7)	1 (3.5)	20 (71.4)	8 (28.6)	16 (57.1)	12 (42.9)
Mudhol	31	24 (77.4)	6 (19.3)	0 (0.0)	1 (3.2)	23 (74.2)	8 (25.8)	23 (74.2)	8 (25.8)
Total	133	97 (73.0)	25 (18.8)	6 (4.5)	5 (3.7)	98 (73.7)	35 (26.3)	86 (64.5)	47 (35.3)

Values in parentheses indicate percentage of villages falling under a particular category over total number of villages coming under a particular taluka

Rajasthan and these decreased with the increasing rainfall towards the east.

While, 31.8 per cent of the groundwater samples analysed were of poor quality for irrigation purpose in Ghataprabha command area and the contributions of marginally saline, marginally alkali, saline and high SAR saline water were 14.7, 6.5, 3.3, 3.3 and 3.9 per cent, respectively. Sood *et al*. (1998) also reported the similar results in Talwandi Sabo tehsil (Punjab).

The water quality analytical data indicated that high SAR saline water existed in Araladhakatti, Kagadal, Jagapur, Hadli, Gadagoli in Malaprabha command area and Biradi, Chinchali, Nandagoan, Maigur, Shegunasi villages in Ghataprabha command area. Saline waters were found in Asuti in Malaprabha and Kuligod, Kullalli, Muttur and Shankratti villages in Ghataprabha command area. Marginally saline waters occurred in about 15 villages in Malaprabha commond and 26 villages in Ghataprabha command area (as per CSSRI, Karnal classification).The SAR ranged from 0.19 to 12.73 (mmol $L^{-1})^{1/2}$ with a mean value of 5.34(mmol $L^{-1})^{1/2}$ .The lowest SAR value was observed in village Bamanwas and the highest value was observed in village Desh Khera,Haryana (Shahid *et al,* 2008).

With respect to water quality for drinking purpose, groundwaters having fluoride content more than 1.5 ppm which is the maximum permissible level fixed by WHO existed in 50 villages in Malaprabha command area and 34 villages in Ghataprabha command area indicating higher percentage of prevalence of groundwaters having F^- content more than 1.5 ppm in Malaprabha command area than Ghataprabha command. Long-term use of groundwaters with fluorite content in excess of 1.0 to 1.5 mg L^{-1} causes fluorosis in human beings (Anonymous 1984, 1991;). About 30 villages in Malaprabha and 47 villages in Ghataprabha command area had nitrate content more than 50 ppm, which respect to heavy metals such as Pb and Ni, none of the samples exceeded the safer limits. Natural contamination of groundwater sources by fluorite (F^-), arsenic and dissolved salts is a major constraint mainly in regions characterized by arid and semi-arid climates (Sudhakar and Mamatha 2004).

About 80.2 and 70.5 per cent of the groundwater resources in Saundatti and Bailhongal were to be unsafe for drinking purpose with respect to fluoride content. The hazard due to nitrate pollution in groundwaters was more in Saundatti taluka (29.6%) followed by Ramdurga taluka in Malaprabha command area, while in Ghataprabha command, percentage of grounwaters unsafe for drinking purpose with respect to fluoride contents ranged from 8.4 per cent (Raibhag) to 30.5 per cent (Gokak).The mineralization of rainfall is fond tobe responsible for increasing the amount of nitrate in water. The presence of excessive nitrate in water is due to man madse domestic activities and fertilizers form fields. Nitrate at high load

Table 3. Sample-wise summary of groundwater analysis of Malaprabha Command Area

Name of the taluka	Total No. of samples analysed	Number of samples falling under the category						No. of samples having F content >1.5ppm	No. of samples having NO_3 content >50 ppm
		Good	Marginally saline	Marginally alkali	Alkali	Saline	High SAR saline		
Bailhongal	61	45 (73.8)	6 (9.8)	5 (8.2)	5 (8.2)	0 (0.0)	0 (0.0)	43 (70.5)	10 (16.4)
Saundatti	81	71 (87.6)	2 (2.5)	1 (1.2)	0 (0.0)	1 (1.2)	6 (7.4)	65 (80.2)	24 (29.6)
Ramdurga	122	106 (86.8)	8 (6.5)	5 (4.09)	3 (2.4)	0 (0.0)	0 (0.0)	12 (9.8)	31 (25.4)
Navalgund	13	2 (15.4)	5 (38.5)	3 (23.0)	0 (0.0)	3 (23.0)	0 (0.0)	5 (38.5)	2 (15.4)
Naragund	17	9 (52.9)	2 (11.8)	0 (0.0)	0 (0.0)	0 (0.0)	6 (35.3)	5 (29.4)	2 (11.8)
Ron	8	1 (12.5)	3 (37.5)	0 (0.0)	0 (0.0)	3 (37.5)	1 (37.5)	1 (37.5)	1 (12.5)
Total	302	234 (77.5)	26 (8.6)	20 (6.6)	8 (2.6)	7 (2.3)	13 (4.3)	131 (43.4)	70 (23.2)

Values in parentheses indicate percentage of samples falling under a particular category over total number of samples analysed coming under a particular taluka

Table 4. Sample-wise summary of groundwater analysis of Ghataprabha Command Area

Name of the taluka	Total No. of samples analysed	Number of samples falling under the category						No. of samples having F content >1.5ppm	No. of samples having NO_3 content >50 ppm
		Good	Marginally saline	Marginally alkali	Alkali	Saline	High SAR saline		
Gokak	118	96 (81.4)	5 (4.2)	12 (10.2)	2 (1.7)	3 (2.5)	0 (0.0)	36 (30.50)	64 (54.2)
Mudhol	104	31 (69.3)	7 (20.7)	1 (4.7)	2 (0.6)	5 (1.3)	44 (3.3)	51 (29.3)	(34.0)
Raibhag	107	71 (66.3)	11 (10.3)	12 (11.2)	5 (4.6)	2 (1.9)	6 (5.6)	9 (8.4)	33 (30.8)
Athani	15	2 (13.3)	7 (46.7)	0 (0.0)	0 (0.0)	2 (13.3)	4 (26.6)	0 (0.0)	4 (26.7)
Chikkodi	40	25 (62.5)	11 (27.5)	1 (2.5)	2 (5.0)	1 (2.5)	0 (0.0)	13 (32.5)	8 (20.0)
Jamkhandi	108	69 (63.9)	14 (13.0)	3 (2.8)	8 (7.4)	8 (7.4)	6 (5.6)	24 (22.2)	48 (44.0)
Total	538	367 (68.2)	79 (14.7)	35 (6.5)	18 (3.3)	18 (3.3)	21 (3.9)	126 (23.4)	2083 (38.7)

Values in parentheses indicate percentage of samples falling under a particular category over total number of samples analysed coming under a particular taluka

may cause eutrophication of aquatic body (Krishna Ram *et al.,* 2007).

Seasonal water quality characteristics in both the command area were also monitored. The resulted indicated a decrease in pH and increase in EC and other ions during summer and the lower concentrations of the ions studied and slightly higher pH values were recorded during the canal open periods.

Conclusion

Based on the results of the present investigation, it can be concluded that Ron taluka in Malaprabha and

Athani taluka in Ghataprabha command areas have poor quality groundwaters unsuitable for irrigation purposes. Regarding the suitability for drinking in Malaprabha command area, the Bailhongal and Saundatti talukas were identified to have high fluoride content while the Saundatti taluka had high nitrate containing water. Similarly in Ghataprabha command area, Gokak taluka is having the problems of unsafe fluoride and nitrate contamination in groundwater. Saline waters were found in Asuti in Malaprabha and Kuligod, Muttur and Shankratti villages in Ghattaprabha command area.

References

Anonymous 1991. Indian *Standards 10500, Indian Standards* – Drinking Water Specifications.

Anonymous 1984. Guidelines *for Drinking water quality, Recommendations*, WHO, Geneva, Vol.1, p.79.

Krishna Ram H, Mohan M, Ramachandra and Vishalakshi Y 2007. Limnological studies on Kolaramma lake Kolar, Karnataka. *Environ. Ecol.* 25(2): 364-367.

Paliwal, K.V. 1972. *I.A.R.I. Monograph* 2, New Delhi.

Richards, L.A. 1954. Diagnosis and improvement of saline and alkali soils. U.S.D.A. Hand Book No. 60. Oxford & IBH Publishing Co., New Delhi.

Shahid, M., Singh, A.P. and Bhandari D.K. 2008. Groundwater Quality Appraisal and Categorization in Julana Block of Jind District, Haryana. Journal of the *Indian Society of Soil Science* 56:123-125.

Sood, A., Verma, U.K., Thomas, A., Sharma, P.K. and Brar, J.S. 1998. Assessment and management of underground waters quality in Talwandi Sabo tehsil of Bathinda district (Punjab). *Journal of the Indian Society of Soil Science* **99**: 421-426.

Sudhakar, M. Rao and Mamatha, P. 2004. Water quality in sustainable water management. *Current Science* **87**: 942-947.

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Post-drainage monitoring approaches for small and large scale sub-surface drainage projects: Case studies from Haryana

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ABSTRACT

Waterlogging and soil salinity in irrigation commands are manifestations of poor water management. Other factors responsible for these problems can be improper geographical, geological and edaphic conditions, which restrict the natural drainage. Drainage measures are generally location specific and depend on understanding of complex relationships among different factors. Agricultural research organizations standardized subsurface technology for varying types of agro-climatic conditions through small scale intensive feasibility studies. Later on technological packages were taken to farmers' fields through large scale drainage projects. The post drainage monitoring of these drainage projects is required to assess the impact of technology. Though variables, which are to be monitored, remain same in monitoring of small and large scale projects, the purposes of monitoring are slightly different. The farmers' reactions to technology, financial investments by governments and farmers, social and economical aspects take over the technical aspects of technology in monitoring of large scale projects. The cost of monitoring is also important limiting factor for large scale projects in view different dimensions and scale of monitoring and therefore indirect indicators to assess the impact are also preferred. The paper illustrates monitoring procedures through two case studies from Haryana, one related to the small scale feasibility study at Hisar while other is related to the large scale drainage project at Jhajjar (Beri).

Key words: canal command, electrolyte concentration, saline soil, sub-surface drainage, waterlogging

Introduction

Water logging and soil salinity problems are adversely affecting agricultural lands in many irrigation commands in India and have posed threats to the sustainability of irrigated agriculture. Need of drainage planning is felt and now it is considered as an important component of irrigation planning. A large number of small-scale research experiments (Rao *et. al.,* 1986) were initiated by different agricultural research institutes state departments, which were culminated into operational research projects in Rajasthan and Haryana (RAJAD 1995; Ton *et al.,* 2000; HOPP, 2004, Kaledhonkar *et al.,* 2010). Later on private investments in terms of public-private partnership, design and implementation of large-scale drainage projects started pouring in the states of Maharashtra and Karnataka. There was a lot of change in the technological aspects of drainage too. The research experiments in different parts of India started with manual installation. Use of clay/concrete drainpipes and gravel filter envelopes was more common during those days. Presently, most of the subsurface drainage project activities such as survey, design, layout and installation are mechanized. Use of corrugated perforated PVC drainpipes and woven/non–woven envelope material has become the accepted practice. In contrast to earlier projects of small areas, new projects are being planned for few thousand hectares. Besides, technological aspects of subsurface drainage, social engineering and environment issues (related to disposal of drainage effluent) require more attention. In view of these developments and huge investment in subsurface drainage projects, the monitoring of large scale drainage projects during planning and design, installation and during post installation period is becoming very important. The Central Soil Salinity Research Institute (CSSRI), Karnal is associated with subsurface drainage since initial experiments on drainage at Sampla in 1984. After successfully conducting small scale drainage experiments, it swiftly got involved in design and installation of large scale drainage projects in Haryana, Maharashtra and Karnataka and is providing technical knowhow to almost all states, facing water logging and soil salinity problems. It is involved in preparing guidelines for monitoring and evaluation of technical, social and economical aspects of large scale drainage installations.

The monitoring of drainage project can be divided into three categories: pre-drainage, during installation of drainage and the post drainage. The pre-drainage and during installation monitoring are mainly related to engineering aspects of design and installation. However, effects of SSD on crops are monitored during post drainage period. Hence post drainage evaluation gets more importance in view of economic and social impact of subsurface drainage. The small scale drainage projects are generally executed to assess feasibility of technology under given agro-climatic conditions while large scale drainage projects are generally monitored to assess socio-economic impact as well as level of adoption of tested technology by farmers. Therefore, aims of both monitorings are different. The CSSRI's experience of monitoring and evaluation of small scale drainage projects at initial stage and large scale drainage projects at later stage, particularly with reference to Haryana, is shared here through two representative case studies; at farm of Central Institute of Research on Buffaloes (CIRB) Farm Drainage Project, Hisar and Drainage Project Jhajjar (Beri), respectively.

Material and methods

The post drainage monitoring of drainage projects is required to assess the impact of technology on controlling water table, soil salinity, groundwater quality and drainage water quality, and simultaneously improvement in crop yields. Though variables, which are to be monitored, remain same in monitoring of small and large scale projects, the purposes of monitoring are slightly different. The small scale projects are generally research studies, conducted to understand feasibility of technology in given set of agro-climatic conditions. However, large scale drainage projects implement the tested technology on farmers' fields. The farmers' reactions to technology, financial investments by governments and farmers, social and economical aspects take over the technical aspects of technology in large scale monitoring. The conflicting interests of farmers in operation of pumps at drainage sumps in case of inland basins, disposal of drainage effluent, and maintenance of drainage system are added aspects in large scale projects. Therefore, monitoring of large scale drainage projects become more complicated compared to small scale projects. In view of new dimensions of monitoring and scale of monitoring, there remains tendency among experts to assess indirect indicators instead of direct indicators for evaluation purpose. Also experts prefer to update monitoring procedures in view of earlier experiences instead of adhering of strict guidelines.

Above mentioned issues of monitoring of small and large drainage projects are discussed in this paper with help of two drainage projects in Haryana. The drainage project at farm of CIRB, Hisar is small scale system of 75 ha with evaporation pond for disposal of drainage effluent. However, Drainage Project at Jhajjar (Beri) is of 800 ha system, approximately. Water table and soil salinity were generally intensively monitored for performance of small scale drainage projects (Rao *et al.,* 1996; Kaledhonkar, *et al.,* 1998; Aheer *et al.,* 1997; Manjunatha *et al.,* 2004).

Spatial and temporal data on soil salinity, groundwater quality, and drainage water quality and crop yields at smaller intervals were collected and analyzed to get better understanding of functioning of the system. But it generally did not happen with large scale projects. Funding agency could not agree for intensive monitoring of water table in Jhajjar (Beri) drainage project area. There were two reasons for it. The maintaining the observation wells in farmers' fields was difficult. As per previous experiences, observation wells got damaged during agricultural operations. Secondly it was assumed that improvement in soil salinity as final result of subsurface drainage system. By monitoring the soil salinity and crop yield, sufficient information about water table / leaching behaviour could be gained. Therefore water table monitoring was not done in the project area. However soil salinity and crop yield data were recorded. Monitoring of disposal drainage effluent from the project area is also important issue in case of drainage systems installed in inland basin without natural outlet (Kamra *et al.,* 2000). However, this issue was not covered in the present study. Drainage effluent was disposed into a drain, which finally drains into Yamuna river. In-situ, evaluation of drainage filter of installed system, after few years of functioning, was also part of post drainage monitoring (Kumbhare and Ritzema, 2000). Separate data were not collected for Jhajjar area; however, it was decided to depend on earlier reports of similar type of studies in Haryana. These two case studies, with help of available data, are discussed in this paper to show different approaches in adopted in monitoring with scale of the projects.

Results and discussion

Study site

The soils of the farm of Central Institute for Research on Buffaloes (CIRB), Hisar located in the semi arid region of Haryana were seriously affected by problem of salinization due to irrigation induced waterlogging problem. A subsurface drainage system in conjunction with an artificially constructed farm pond of 1 ha surface area (for disposal or management of drainage effluent) was in operation since 1991. The system was designed for amelioration and management of 52 ha waterlogged saline soils in the farm, which forms core of research activities. Installation of subsurface drainage system to reclaim additional 75 ha area and construction of an evaporation pond on 1.75 ha area, initiated during 1993, was completed in summer of 1996 (Rao *et al.,* 1987; Kamra *et al.,* 2000).

Assessing impact of subsurface drainage system

Kaledhonkar *et al.* (1998) regularly monitored water table, soil salinity, groundwater quality, drainage water quality and crop yields in drainage research area. to assess effectiveness of subsurface drainage in controlling soil salinity and water table as well as in evaluating drainage design assumptions. Soil salinity and crop yield data at grid of 30* 30 m were collected on seasonal basis. Watertable depth and drainage water quality were collected on weekly basis. Salinity of 30 cm layer in 52 ha drainage area gradually reduced from initial values ranging from 10 to 70 dS/m to salinity of 2 to 7 dS/m as result of operation of system. In fact the area having soil salinity (ECe) more than 10 dS/m in 30 cm soil layer reduced from 84% to 7% within 2 years after installation of drainage system. This results suggested that there was 7% area, where leaching was not effective. There can be many reasons for this thing. There might be improper land leveling or improper ponding of water. Bunds might be constructed to improve the leaching. Sometimes, there might be choking of lateral lines that need be properly assessed. These results further suggested that there was need to have salt tolerant crops in high saline areas. As part of management strategy, Berseem was grown on non-saline fields while Barley was grown on saline fields.

Monitoring of water table data gave us important information about functioning of lateral lines and performance of drainage filters. Salinity of drainage water has also reduced from about 8 dS/m during early years to value of 2.2 dS/m though there were small variations during different seasons. Finally, it reached to 0.9 dS/m and drainage water reuse was proposed during rabi season. With consequent reduction in soil salinity, there was steady increase in the area under cropping as well as yields of kharif (sorghum, bajara) and rabi (berseem, barley, oat) crops. The yields of berseem and barley increase two to three times over the years, though there were considerable variations within the area due to different periods of effective leaching. Proper land, agronomic and water management practices including regular pumping of drainage effluent into the farm pond were, however, pre requisites for sustaining high crop yields in research area of CIRB, farm at Hisar.

Subsurface drainage system was evaluated for its design assumptions of hydraulic conductivity and drainage coefficient. Data on lateral drain discharge, q (m/day) and watertable head above the drain axis at mid drain spacing, h (m) were collected during the periods of watertable recession to determine field hydraulic conductivity (K) in drainage project area. The computed effective K value was compared with hydraulic conductivity calculated as geometric mean of point K measurements by auger hole and inverse auger hole method conducted during drainage investigations and used in drainage design. The estimated effective K of 0.47 m/day compares well with design K value of 0.5 m/day based on point determinations. Similarly observed drain discharge hydrographs of different years were also evaluated vis-a-vis design drainage coefficient. It was found that the maximum observed drainage discharge rate never exceeded the design drainage coefficient of 1.5 mm/day during the operation span of drainage system

The arid areas similar to Hisar, which have no suitable outlets for disposal of drainage effluent, evaporation ponds about 3- 5% of the drainage area seem to meet the storage and evaporation demands of drainage effluent. As expected, the quality of pond water (especially SAR) was deteriorating with time. It was found that peripheral drains provided on the sides of pond at Hisar restricted contamination of groundwater to within a radial distance of 15 m from pond.

Large Scale Drainage Project at Jhajjar (Beri)

Study site

The state of Haryana is located in the northwestern part of India between latitude 27°39′ to 30° 55′ North and longitude 74° 28′ to 77°37′ East covering a geographical area of 4.4 million ha. About 94% of the state is covered by 600 to 3,000 m thick quaternary alluvium that forms part of the Indo Gangetic alluvial system. The main rivers in the region are the Yamuna and the Ghaggar forming the eastern and approximate northwestern boundaries of State. While these two rivers constituting Yamuna and Ghaggar drainage basin drain parts of the state, yet another part not drained by these rivers is known as internal drainage basin. The Jhajjar study area (Fig. 1) falls in the internal drainage basin.

The climate of the state varies from sub humid to arid. The annual rainfall varies from 1100 mm in the Northeast to below 250 mm in the extreme west. At Jhajjar the average annual rainfall from 1993 to 2003 was 494 mm. About 80 90% of the total rainfall occurs during the monsoon period of June September. The maximum temperature reaches up to 45°C in summer while in winter season minimum temperature falls up to 1°C in the month of January. The evaporation in the study area remains high and in most months it exceeds the rainfall except in July and August.

Assessing effects of dewatering on soil salinity and crop yield

Dewatering of drainage water from different drainage blocks of Jhajjar project area was coordinated by HOPP and the pumping details were recorded. The block was unit for monitoring rather than individual field. The map of Jhajjar drainage area and the map of monitored subsurface drainage blocks of the drainage area are shown in Fig. 2 and Fig. 3, respectively. The dewatering data were analyzed to estimate temporal changes in pumped

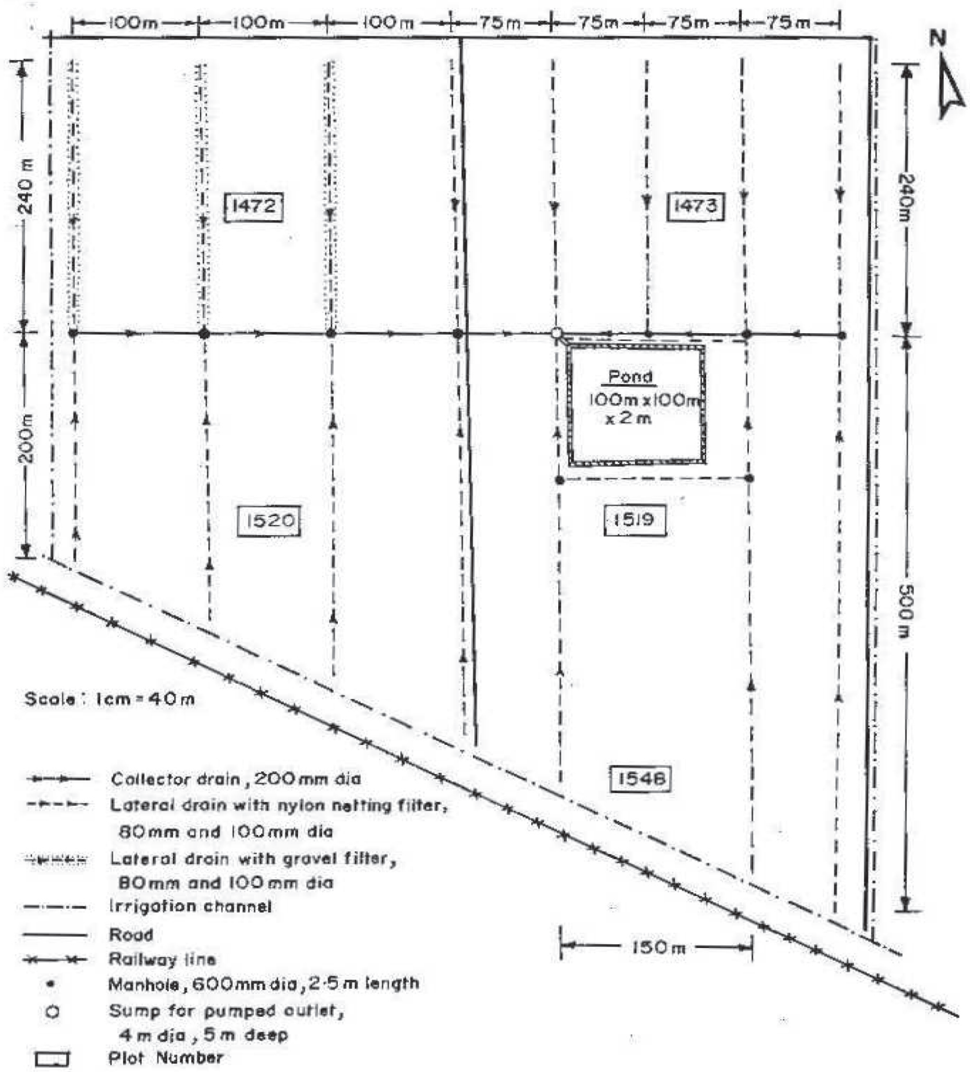

Fig. 1. Layout of subsurface drainage system and evaporation pond at CIRB farm, Hisar

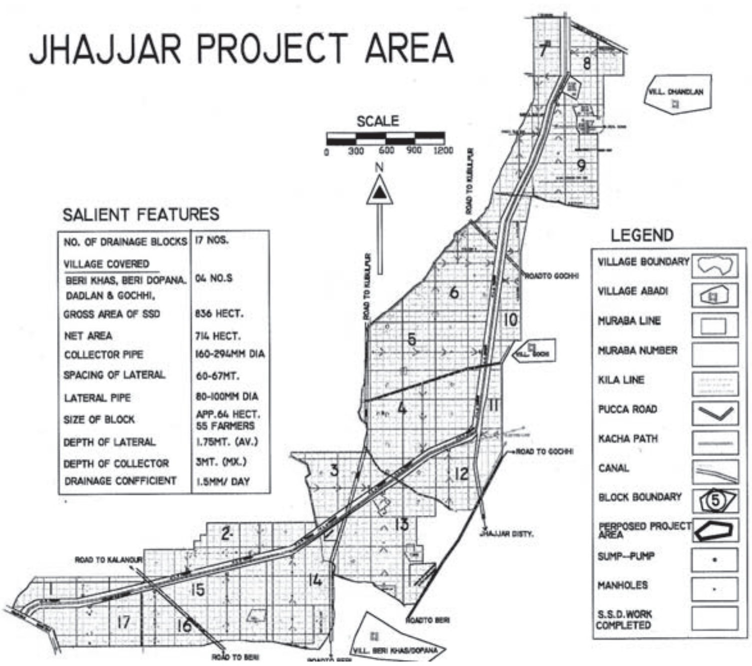

Fig. 2. Map of Jhajjar (Beri) drainage area

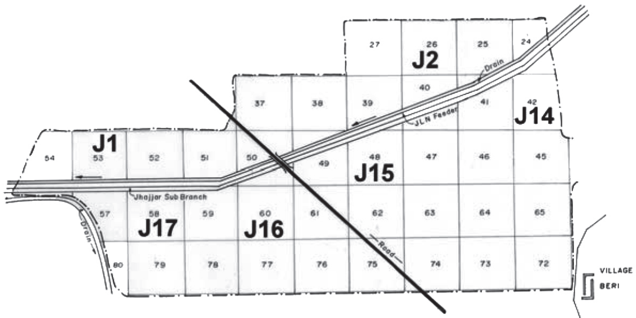

Fig. 3. Map of monitored subsurface drainage blocks of Jhajjar drainage area

Drainage water pumping volume from each drainage block was used to estimate the drainage water pumping depth by dividing by drainage area. The block wise data are given in Table 1. The maximum pumping was done from block no. J17 while minimum pumping was done from block no. J1. The dewatering data till March 2005 were complied during this analysis. The sampling points for soil salinity for different monitored blocks are also provided in Table 1. In general, representative soil sample was collected from central plot of each monitored unit of 25 acre (approximately 10 ha) locally called as *Muraba*

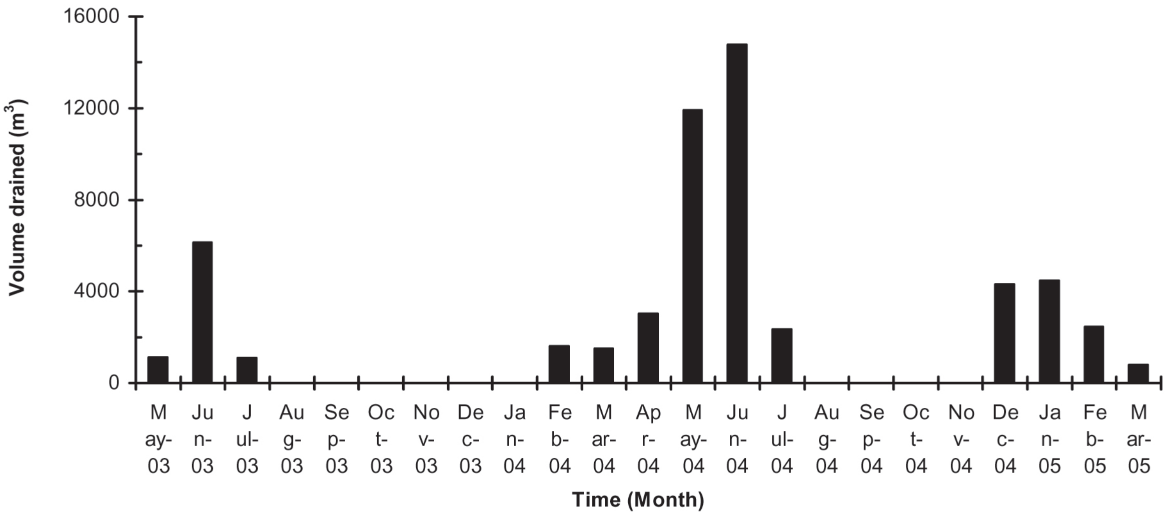

Fig. 4. Temporal variations in volume of pumped drain water for Beri project area

water quantities (Fig. 4). Pumping was mainly done during the periods of May 2003 to July 2003, February 2004 to July 2004 and December 2004 to May 2005. Maximum pumping was done in the month of June 2004. Drainage block wise pumped water volumes are shown in Fig. 5.

and soil salinity values from such *Murabas* were used to calculate the average soil salinity value for drainage block during May 2005.

In general, dewatering had direct effect on soil salinity (Fig. 6). The lowest pumping was done in block J1, which

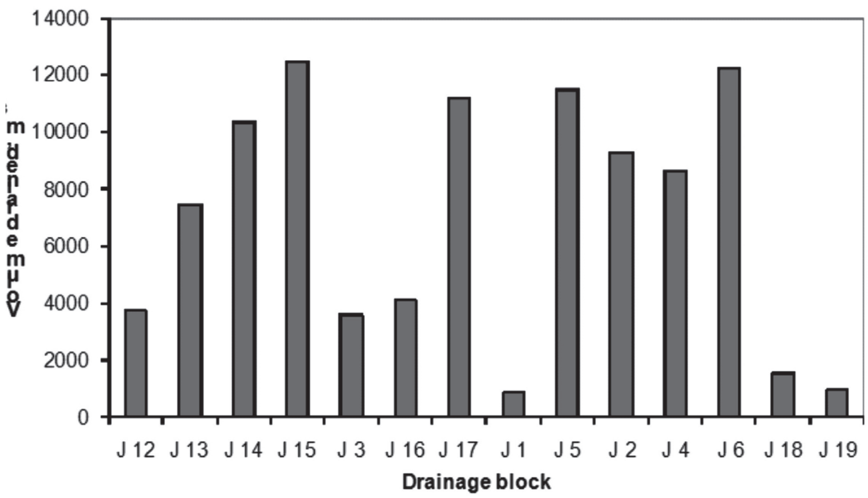

Fig. 5. Block wise pumped water volume

Table 1. Drainage volumes and pumping depths for different drainage blocks

SN	Block No	Area, ha	Volume drained (m^3)	Pumping depth (cm)	Soil salinity sampling points
1	J 1	16.5	827.97	0.502	5
2	J 2	48	9288	1.935	8
3	J 3	41	3599.8	0.878	5
4	J 4	78	8673.6	1.112	9
5	J 5	70	11515	1.645	8
6	J 6	77	12235.3	1.589	10
7	J 12	35	3780	1.018	6
8	J 13	70	7448	1.064	10
9	J 14	68	10363.2	1.524	8
10	J 15	63	12486.6	1.982	6
11	J 16	30	4104	1.368	5
12	J 17	49	11230.8	2.292	6
13	J 18	80	1512	0.189	11
14	J 19	79.6	971.916	0.122	Nil

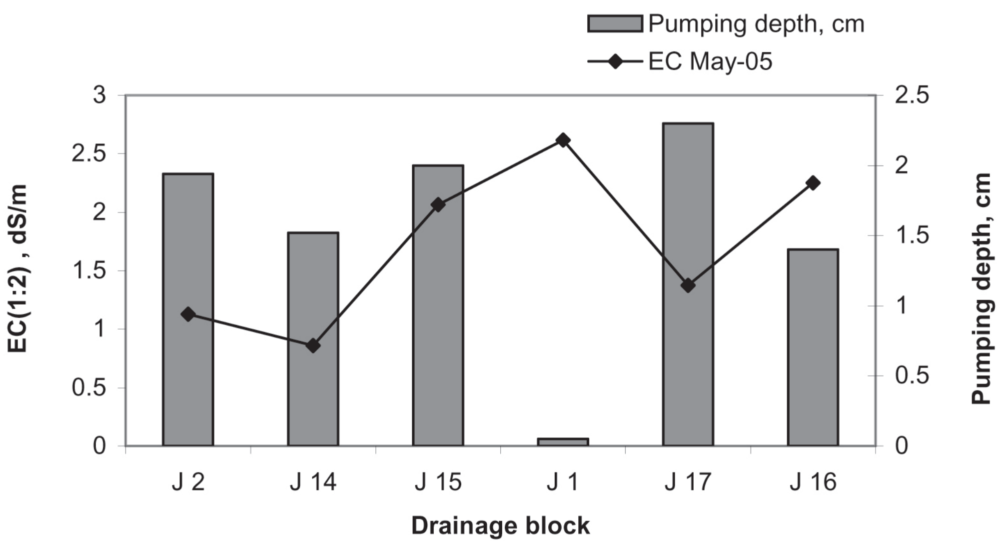

Fig. 6. Variations in salinity EC (1:2) with depth of pumping for drainage blocks

showed highest salinity (EC 1:2). In other blocks, pumping was relatively higher than block J1 and they showed lower salinity than block J1. Comparison of soil salinity EC (1:2) during May and October 2005 is shown in Fig. 7. Except block no. J 17, there was reduction in soil salinity from May to October 2005 as result of leaching during monsoon. Soil salinity of block J17 increased though it had maximum pumping depth 2.292 cm till 2005. It clearly suggested that pumped water was used for irrigation of paddy crop by farmers in that block and it resulted in increase in soil salinity of the block.

The effect of soil salinity on crop yield was also monitored through crop cutting experiments at different HOPP drainage sites in Haryana. The soil salinity and wheat yield values are shown in Fig. 8 and soil salinity and paddy yield values are shown in Fig. 9. Though crop yield is influenced by different management practices besides soil salinity, there is clear trend indicating that higher salinity is associated with lower yield.

Impact of subsurface drainage system on soil salinity and wheat crop yield

Temporal monitoring of soil and crop improvements in a drainage project provides a convenient way for impact assessment of subsurface drainage systems in waterlogged saline lands. To achieve this objective, monitoring and evaluation of Jhajjar project was done from rabi of 2004-05 to Rabi 2006-07. Based on the detailed survey of the projects, permanent grid locations were marked on the maps of the project area for data collection. An area-random samples were taken with the help of a grid of pre-determined density (330 m x 307 m), in line with the grid system of the revenue maps, upon which every plot of 1 acre (0.4 ha) was systematically numbered. This grid

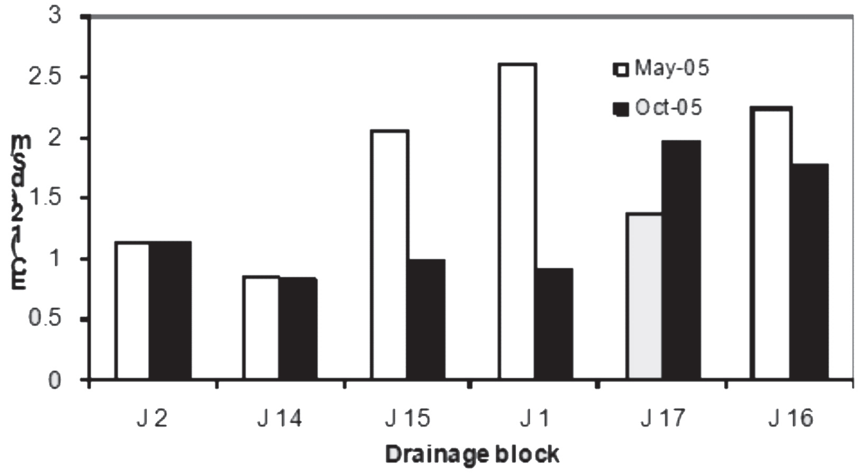

Fig. 7. Temporal changes in soil salinity values

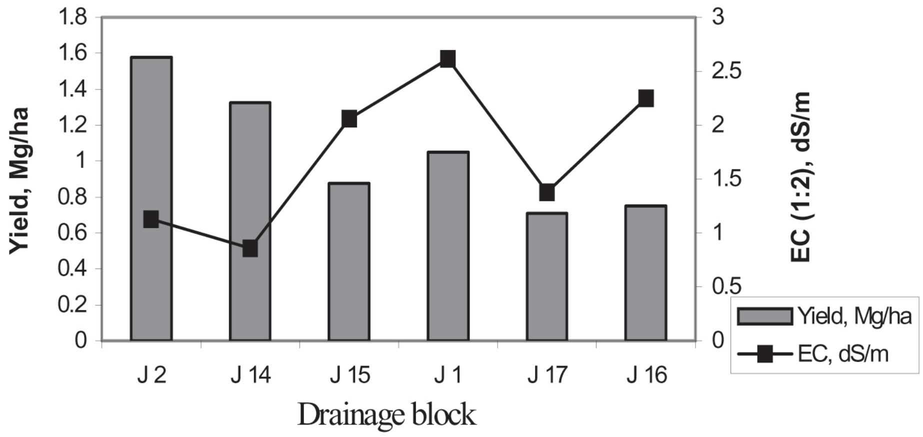

Fig. 8. Effect of soil salinity on wheat yield in drainage blocks

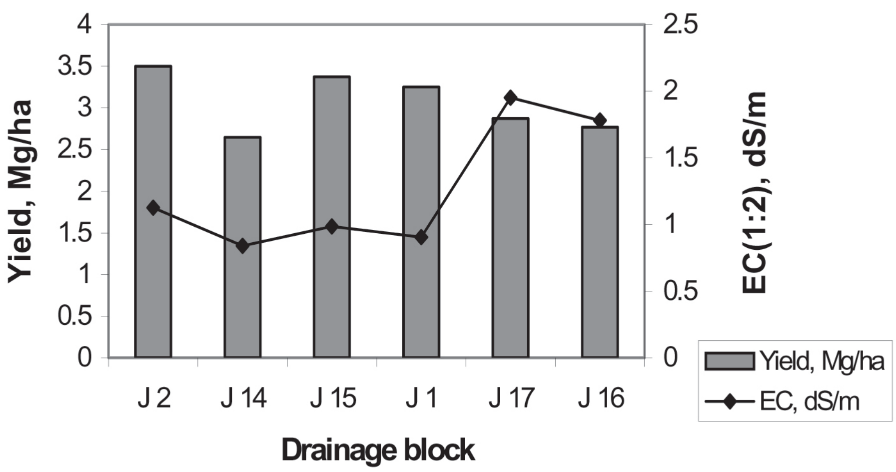

Fig. 9. Effect of soil salinity on paddy yield in drainage blocks

size was higher compared to grid size of 30*30 m in small scale projects. The main reason for the area-random sampling was the commonly erratic distribution of soil salinity throughout the area. The number of sample locations was fixed as 37 in Jhajjar Project, keeping in mind the possibility of sub-dividing the area according to major soil type, and/or farm type, and size of holding. The owners of the sample plots were identified with the help of revenue records and maps. In the selected plots, soil sampling and crop cutting were done from each location. Soil sampling and crop cutting were done during the *rabi* season of 2005-06. For the assessment of soil salinity and alkalinity problems, soil samples were collected from 0-30 cm soil depth. Crop cuttings were

Table 2. Improvement in soil salinity and wheat yield with provision of subsurface drainage system

Variable	2004-05	2006-07	% increse (+) / decrease (-)
EC (1:2), dS/m	1.61 (0.20 – 6.33)	1.32(0.17 – 3.40)	- 18.01
Wheat yield (t/ha)	1.11(0.17 – 3.42)	1.95(0.50 – 3.50)	+ 75.68

Table 3. Area wise improvement in Jhajjar drainage project

Class	Lower Salinity Limit EC (1:2), dS/m	Higher Salinity Limit EC (1:2), dS/m	Area (ha) under salinity class		
			Rabi 2004-05	Rabi 2005-06	Rabi 2006-07
1	0.17	1.20	230	220	220
2	1.20	2.23	40	50	50
3	2.23	3.26	30	60	90
4	3.26	4.29	50	0	10
5	4.29	5.31	0	20	0
6	5.31	6.34	20	20	0

done from the same locations taken from an area of $12m^2$ (4m x 3m). The collected soil samples were air-dried and crushed to pass through a 2-mm sieve. The processed samples were analyzed for soil EC and pH in 1: 2, soil: water suspension. Wheat grain yields were recorded on air-dry basis. The results obtained during the 2004-05 and 2006-07 rabi season are given in Table 2.

There was reduction in soil salinity EC (1:2) dS/m from 1.61 to 1.32 drainage project area. It has resulted in improving the wheat yield. Alkalinity problem is not so serious, only a few locations indicated alkalinity problem. The average pH (1:2) was 8.0 (7.2 – 9.0) during *rabi* of 2004-05 while it was observed as 8.26 (7.74 – 8.72) during 2006-07.

Assessing area-wise improvement in soil salinity in drainage project area

Temporal data on soil salinity were monitored for assessing improvement in soil salinity as result of subsurface drainage system. The soil salinity value was measured in dS/m and was determined from 1 part soil: 2 part water solution. Three soil salinity data sets namely; rabi 2004-05, rabi 2005-06 and rabi 2006-07 were selected of Jhajjar project area. The number salinity classes for drainage project area were determined by following formula.

$$m = 1 + 3.3\log(n)$$

where, m is number of salinity classes and n is the number of samples taken from project area.

The lowest and largest soil salinity values were determined from the above-mentioned salinity data sets. The difference between lowest and largest soil salinity values was calculated and it was divided by number of classes to determine the class interval. Starting from the lowest value of soil salinity and adding the class interval to it, lower and upper limits for the first class were estimated. By the same procedure, upper and lower limits for all classes were worked out.

The soil salinity data values falling under each class were determined for rabi 2004-05, rabi 2005-06 and rabi 2006-07 for Jhajjar project area. One data value represents the 10 ha area (25 acre). The area under each soil salinity class was estimated considering number of data values occurring in that class. The results of analysis are shown in Table 3. Table 3 suggests that area under soil salinity having EC (1:2) value less than 3.26 was 300 ha in *rabi* 2004-05. It increased to 330 ha in *rabi* 2005-06 and to 360 ha in *rabi* 2006-07. Thus provision of SSD in Jhajjar area helped in reduction in soil salinity and consequent increase in crop yield.

In-situ testing of performance of filter material

Non-woven polypropylene for lateral was used as filter material for laterals. Performance of filter material was not studied this project as post drainage performance for similar type of soil and climatic conditions was done in 1236 ha Gohana project in Haryana, which was implemented during 1994 to 1999. The Gohana project is approximately 50 km away from Jhajjar project. On the basis of the Gohana study, specifications of filter for this project were standardized. In Gohana project, performance of filter was assessed on the basis of quantity of sediment deposition in the lateral drainpipes after 2 to 4 year of installation of subsurface drainage system. Visual analysis showed that drainpipe in some blocks contained nearly no sediment and < 1 cm layer of sediment found in some areas. The sediment deposition in drainpipe with different polypropylene enveloping material with apparent opening size (O_{90}) as 320, 400 and 366 um (micron) is shown in Table 4. On the basis of results, it was concluded

Table 4. Sediment deposition in exhumed drainpipe with different envelope material under Gohana subsurface drainage project

Drainpipe/ Envelope	Drain spacing (m)	Soil retained (g/m)	Percent by pipe section
PVC/Polypropylene 320 um	60	335	3.9
PVC/Polypropylene loose fibre 400 um	60	150	1.7
PVC/Polypropylene 366 um	60	208	2.4

(Source: Kumbhare, P.S. and Ritzema, H.P., 2000)

that the lateral drainpipe and envelope material functioned well and polypropylene with more 300 micron was recommended for installation in Haryana having similar soil and climatic conditions like Gohana.

Economics of crop production

The subsurface drainage (SSD) is an important technology for managing the saline and waterlogged lands. It requires huge investment. It is also important to note that farmers in waterlogged areas remain resource poor and financially weak. They have to investment money either from government support or loan. Therefore, assessing the economic feasibility of the drainage system becomes very much necessary (Singh *et. al*., 2000, Datta *et al*., 2000, Tripathi and Sharma, 2009). Data collection for economic analysis for Jhajjar project was done after wheat crop of 2005-06 and then it was discontinued due to limited scientific staff. However, it continued for similar type of project at Charkhi Dadri in Haryana located in the same climatic region. The economic analysis for both paddy and wheat was done for this project. The overall increase in wheat and paddy yields over existing yields was 56 and 25 percent, respectively. The economic analysis for paddy crop revealed that Benefit Cost Ratio on operational cost was 2.91. The Benefit-Cost Ratio was 1.81 on the basis of total cost. Similarly for wheat, Benefit-Cost Ratio on operational cost was 1.93 on an average ranging from 1.69 to 2.28. The Benefit-Cost Ratio on the basis of total cost was 1.24. The results indicated that the salinity and water logging problems could be managed to large extent with provision of subsurface drainage system and satisfactory production levels could be achieved.

Conclusions

Subsurface drainage experiments in different parts of India have helped in developing the confidence about different aspects of the technology and large scale drainage projects are coming up, of course at slow pace, to deal with the water logging and soil salinity problems. Scale and purpose of monitoring both are different in case of large scale drainage projects. Therefore, data collection for evaluation and monitoring of large scale projects can not be as intensive as small scale experiments. The present case study has highlighted some of the important aspects of evaluation process of large scale projects. Funding and implementation agencies always prefer to study economic and social aspects of the technology to know benefits of investment made to farmers' community and these aspects generally take over the technical aspects as understanding about them help in better management of the projects. It is important to note that funding agencies may not take interest in collection of data for particular analysis, if the results are almost certain or as per expected trends. In such cases, it is always better to take benefits of previous experiences in similar type of situations. Management of drainage water through conjunctive use of canal and drainage water for salt tolerant crops/ forestry and fish culture need to be important area of monitoring program, though it was not covered in this case study due to lack of sufficient data. Though the monitoring exercises sometimes appear customary, these exercises need to be done with utmost sincerity as the results, emerging from exercises, have more practical relevance in technical and social domains. Further, such monitoring exercises also help in mid-term correction of technology for its own sustainability.

References

Aheer, H.L., V.K. Bhatia, R.D. Sharma and Sewa Ram. 1997. Effect of drain depth on watertable management, water quality and soil salinity. In: Hooja, R, N.A.Visvanatha and S.N. Mundra. Managing Drainage and Irrigation - The Case of Chamba, Rajasthan CAD and RAJAD Projects. Himanshu Publications, Udaipur, India, pp: 173-180.

Datta, K.K., Jong C.de., Singh, O.P., 2000. Reclaiming salt affected land through drainage in Haryana, India: A financial analysis. Agricultural Water Management, Vol. 46:55-71.

Haryana Operational Pilot Project (HOPP), 2004. Report on Benefits of Subsurface Drainage in Gohana. HOPP, Department of Agriculture, Haryana.

Kaledhonkar, M.J., Gupta, S.K. and Singh, Gurbachan, 2010. Overview of research and development opportunities and challenges for subsurface drainage in India. In: Abstracts of 60th IEC of ICID and 5th Asian Regional Conference on Improvement in Efficiency in Irrigation Projects through Technology Upgradation and Better Operation and Maintenance. Organized by CBIP, New Delhi and INCID, New Delhi at Vigyan Bhawan, New Delhi, p210-211.

Kaledhonkar, M.J., Kamra, S.K., Sharma, D.P. 1998. Drainage measures for control of waterlogging in semi-arid regions. In: Proc.9th National Symposium on Hydrology, Amritsar, 26-27th Nov. 1998, at Amritsar, 97-104.

Kamra, S.K, Kaledhonkar, M.J., Sharma, D.P. 2000. Evaporation ponds for disposal of saline drainage effluent in inland saline soils. In Proceedings of Role of Drainage and Challenges in 21st Century, Proceedings of 8th ICID International Drainage Workshop, at New Delhi (India) during 31st Jan. to 4th Feb. 2000, Vol. III, 269-279.

Kumbhare, P.S. and H.P. Ritzema. 2000. Need, Selection and Design of Synthetic Envelopes for Subsurface Drainage in Clay and Sandy Loam Soils of India. In: Proceedings, 8th ICID International Drainage Workshop, Delhi, India, Volume vol.4, p.VI163-VI175.

Manjunatha, M.V., Oosterbaan, R.J., Gupta, S.K., Rajkumar, H. and Jansen, H., 2004. Performance of subsurface drains for reclaiming waterlogged saline lands under rolling topography in Tungabhadra irrigation project in India. Agricultural Water Management, 69: 69-82.

RAJAD, 1995. Analysis of Subsurface Drainage Design Criteria. Chambal Command Area Development & Canadian International Development Agency. Kota,Rajasthan.

Rao, K.V.G.K, Sharma, D.P., Kamra, S.K, Kaledhonkar, M.J. 1996. Performance evaluation of subsurface drainage for soil salinity control. In: Proc.16th International congress of ICI, Cario, 45-42.

Rao, K.V.G.K., Gupta, R.K. and Kamra, S.K. 1987. Reclamation of Waterlogged High SAR Saline Soils: a feasibility report for CIRB farm, Hisar, CSSRI, Karnal, 21p.

Rao, K.V.G.K., Singh, O.P., Gupta, R.K., Kamra, S.K., Pandey, R.S., Kumbhare, P.S. and Abrol, I.P., 1986. Drainage Investigations for Salinity Control in Haryana. Bulletin No. 10, Central Soil Salinity Research Institute, Karnal, p 95.

Singh, R.V., Chauhan, M.S., Solanki, A.S., 2000. Socio-economic issues for management of drainage projects", 8th ICID International Workshop, 31st Jan.-4th Feb.2000, New Delhi, Vol. III, pp. 59-70.

Ton van Achthoven, H.S. Lohan and Bradley W. Parlin, 2000.The reclamation of waterlogged and saline lands with subsurface drainage: an overview of the Haryana Operational Pilot Project. In: Proceedings of ICLRM, New Delhi November 2000.

Tripathi, R.S. and Sharma, D.P., 2009. Impact of subsurface drainage on resource use efficiency in salinity affected irrigated farms of Haryana (India). In: Abstracts 60th IEC of ICID and 5th Asian Regional Conference on Improvement in Efficiency in Irrigation Projects through Technology Upgradation and Better Operation and Maintenance. Organized by CBIP, New Delhi and INCID, New Delhi at Vigyan Bhawan, New Delhi, p206-207.

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Delineation and characterization of salt affected and waterlogged areas in the Indo-Gangetic Plain of Central Haryana (District Kurukshetra) for reclamation and management

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ABSTRACT

The interpretation of geo-coded IRS imageries coupled with ground truth and soil studies indicated the presence of sodic soils as barren white patches, associated with cropped and forest areas. The accumulation of alkaline Na_2CO_3 and $NaHCO_3$ salts in undrained areas favoured sodic soil formation in the Gangetic plain of Central Haryana covering Kurukshetra district. The high clay content and presence of $CaCO_3$ concretions (*calcretes*) resulted in poor drainage and waterlogging. The high sodium content caused development of high SAR, soil alkalinity and high pH. The sodic soils are characterized as very deep, pale brown to dark yellowish brown soil matrix and showed few to common yellowish brown mottles in sub-surface horizons. These soils can be reclaimed with suitable dosages of amendments like gypsum or pyrites and better management practices.

Key words: management, reclamation, remote sensing, salt affected soils

Introduction

Out of 6.7 M ha salt affected soils in the country, 0.23 Mha is distributed in the arid and semiarid regions of Haryana (NRSA, 1997). The primary process involved transportation and deposition of alkaline salts from the Himalayas and Siwalik to the Gangetic plain (Bhargava *et al.,* 1980). Image interpretation showed that old levees, relict flood plain and poorly drained low-lying flats are the common topographic zones showing salt infestation along the Gangetic alluvial plain of Haryana (Manchanda and Iyer, 1983). By adopting gypsum based land reclamation technology at larger scale, significant areas of salt affected soils in Haryana have been reclaimed (Abrol and Bhumbla, 1971). The success of land reclamation was more pronounced in areas under canal irrigation and underlain by good quality ground water. Soil alkalization occurred in the Ghaggar and Markanda plains in Kurukshetra district as a result of irrigation with sodic ground water (Manchanda, 1976; Gupta, 2010). The problems of waterlogging were also reported in irrigated areas causing low productivity (Tanwar, 1996). The present study is aimed to delineate and characterize salt affected soils and waterlogged areas in Kurukshetra district for reclamation and management.

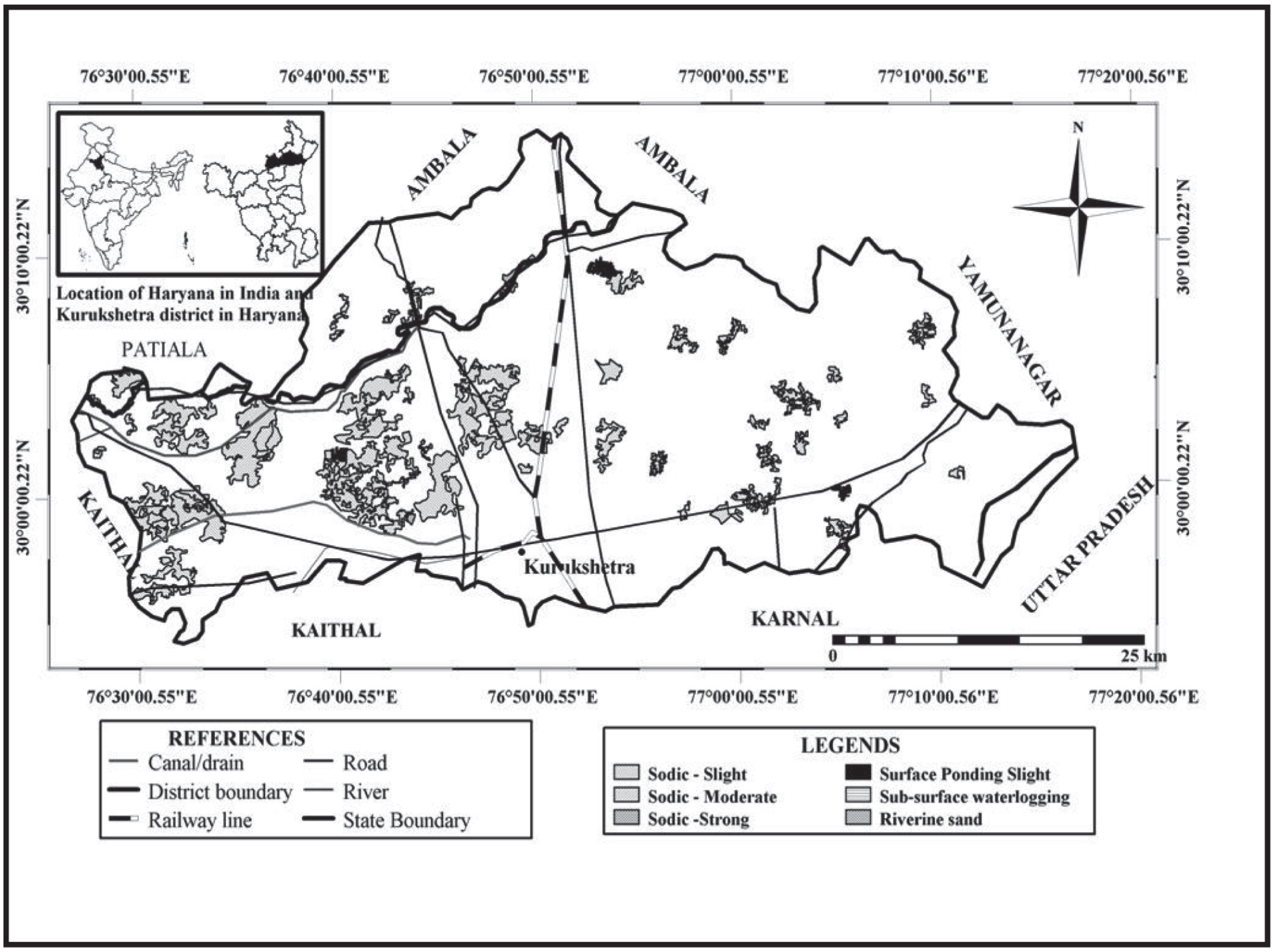
Material and Methods

Study area

The study area (1530 sq. km) lies between 29°47′ 31.12″ and 30°15′29.80″N latitude and between 76°09′ 10.74″ and 77°19′07.92″E longitude with an altitude 253m above mean sea level. The average annual rainfall is 608 mm, mean winter temperature is 12.7^{0}C and mean summer temperature is 38.5^{0}C. The area falls under the old Gangetic alluvial plain and is drained by the Yamuna, Ghaggar and its tributaries *viz.*, Markanda, Saraswati, Chautang and Tangri; and other seasonal streams *viz.*, Sahibi, Dohan and Krishnawati originating from the Aravalli ranges. The irrigation through Western Yamuna (WJC), Bhakra canals and tube-wells altered the moisture regime and chemical characteristics of soils leading to salt infestations, waterlogging and low productivity (Singh, 2009).

The geo-coded False Colour Composites (FCC) with band combination of B321 (NIR, R, G) and B432 (SWIR, NIR, R) of IRS LISS III (Resourcesat) on 1:50,000 scale for March, June and October 2006 were visually interpreted to delineate salt affected soils and waterlogged areas. The interpreted units showing spatial coverage of salt affected soils were transferred on the digitized base map using ILWIS GIS (Fig.1).

Ground truth was conducted to locate the salt affected soils during March 2007 and waterlogged areas in October 2007. A total of 20 soil profiles, 10 mini pits and 16 auger bores were studied for morphology and pedons were classified as per Soil Taxonomy (Soil Survey Division Staff 2004, Soil Survey Staff 1998). Horizon-wise soil samples were analyzed for soluble ions (Na^+, K^+, Ca^{2+}, Mg^{2+}, CO_3^{2-}, HCO_3^- and Cl^-), pH, ECe, $CaCO_3$, organic



carbon, CEC,. ESP and soil separates (sand, silt and clay) using standard procedure (Richards, 1954; Jackson, 1986). Fifteen water samples were analyzed for quality parameters. The reclamation, management and use potentials of soils were also suggested.

Results and Discussion

Mapping of salt affected soils

The interpretation of IRS data showed prominent features for crop (red to dark red), pasture and scrublands (dark green), forest (brown to dark brown), waterlogged (irregular dark blue or blue-black tones) and salt affected soils (white salt crust) (Fig. 1). The waterlogged areas (*surface ponding*, 363 ha) showed prominent energy absorption in IRS data at Band 4 (SWIR). In the irrigated areas, mixed spectral signatures ranging from grayish to dark grayish tones with red mottles showed poor vegetative growth of crops such as wheat and mustard, due to high water table (*sub-surface waterlogging*) in areas with poor drainage. Salt efflorescence at surface is identified with strong spectral signatures from barren salt crusts (5731 ha) and stressed vegetations (10409 ha) in irrigated areas with salty ground water

Characteristics of salt affected soils and waters

During ground truth survey, soil and water samples were collected from the salt affected and waterlogged areas for physico-chemical characterization and quality appraisal. The salt affected soils are characterized as strong (34 ha), moderate (5697 ha) and slight (10409 ha) based on field study and physico-chemical characteristics. Salient characteristics of four representative pedons were presented to show soil alkalinity, composition of soluble salts and pedogenic nature of soils (Table 1). Morphological characteristics ranges from deep to very deep, pale brown to dark yellowish brown colour, sandy loam to sandy clay loam /clay loam texture, medium to strong, coarse to fine angular/subangular blocky structure, sticky, plastic to very sticky, very plastic consistence, presence of few to abundant $CaCO_3$ nodules/concretions and moist to wet sub-surface horizons. A few iron and manganese mottling were found in subsurface (50 cm) layers of P3 (Markanda plain) and P4 (Ghaggar plain), possibly due to prolonged waterlogging. Significant contents of $CaCO_3$ concretions (2-5 cm, 10-30%) were found at 1m depth in P2 and P4. The textural changes occurred from sandy loam to sandy clay loam and sandy clay loam to clay loam at P1, P2 and P4 apparently due

Table 1. Physico-chemical characteristics of soils in Kurukshetra district

Horizon	Depth (cm)	pHs	ECe (dS m^{-1})	Na^+	K^+	Ca^{2+}+ Mg^{2+}	CO_3^{-}+ HCO_3^-	Cl^-	SAR	OC	$CaCO_3$	ESP	CEC (cmol kg^{-1})	Sand	Silt	Clay	Texture
				(me L^{-1})						(%)				(%)			
P1:29°59′54.3′′N 76°25′41.3′′E Coarse-loamy mixed Typic Natrustalf, sodic GW, Ghaggar plain, Kikar, *Prosopis juliflora* plantation																	
A1	0-14	9.6	7.4	98.7	0.9	4.0	17.0	31.0	49.3	0.08	2.45	49.6	13.1	71.2	14.9	13.7	sl
AB	14-40	10.0	5.5	80.0	0.2	4.0	21.0	18.0	40.0	0.06	2.45	51.8	8.8	61.9	21.6	16.3	sl
B21t	40-82	10.1	4.6	70.4	0.1	3.0	28.5	15.0	40.6	0.03	0.98	76.9	11.1	58.8	20.0	21.0	scl
B22t	82-109	10.2	5.3	83.9	0.1	3.0	27.5	12.0	48.4	0.02	1.47	54.1	13.9	58.6	18.6	22.6	scl
C	109-139	9.8	4.5	75.8	0.1	3.0	18.5	11.5	43.8	0.02	2.85	43.2	9.5	63.2	20.1	16.7	sl
P2 29°59′02.7′′N 76°59′37.6′′E Coarse-loamy mixed Typic Natrustalf, highly sodic, good quality GW, Yamuna plain, forestry plants																	
A1	0-12	9.8	1.2	11.5	0.1	1.0	15.7	3.5	11.5	0.17	1.3	46.8	21.6	59.0	23.0	18.0	sl
B21t	12-28	10.7	5.3	54.0	0.1	1.5	30.2	12.5	44.1	0.11	1.0	56.5	26.3	53.0	22.0	25.0	scl
B22t	28-58	10.6	6.2	60.6	0.1	1.0	27.5	10.5	60.6	0.17	2.0	51.8	22.0	52.0	24.0	24.0	scl
B23t	58-99	10.7	7.6	67.1	0.1	1.0	31.5	12.0	67.1	0.11	3.3	50.0	21.2	52.0	27.0	21.0	scl
Ck	99-142	10.5	8.5	75.4	0.1	1.0	35.5	12.5	75.4	0.11	4.9	55.0	21.0	53.0	28.5	18.5	sl
P3 30°02′33.6′′N 76°51′40.7′′E Fine-loamy mixed Sodic Haplustept*, moderately sodic, cropped (rice), good quality GW, Markanda plain																	
Ap	0-15	9.3	2.4	28.6	0.2	3.0	5.0	25.0	16.5	0.18	5.3	50.0	13.2	51.3	25.1	23.4	scl
AB	15-39	9.7	2.6	33.0	0.1	2.0	4.0	20.0	23.3	0.08	1.7	94.6	15.5	43.9	31.1	24.8	1
Bw1	39-76	10.1	4.0	53.9	0.1	2.0	10.0	25.0	38.1	0.08	1.3	94.2	15.9	47.3	26.8	25.8	scl
Bw2	76-105	10.2	5.9	96.7	0.2	2.0	12.5	30.0	68.3	0.08	1.7	83.1	18.4	48.1	24.7	27.0	scl
Bw3	105-149	10.0	6.6	99.5	0.2	2.0	15.5	32.0	70.3	0.05	1.9	89.7	16.8	46.2	25.8	28.0	scl
P4 30°08′56.3′′N 76°24′37.2′′E Fine-loamy mixed Typic Natrustalf, reclaimed sodic, partially cropped, sodic GW, Ghaggar plain																	
Ap	0-18	9.1	1.2	13.3	0.1	1.5	5.0	5.0	10.8	0.6	4.4	53.1	19.2	47.1	28.1	24.8	scl
AB	18-41	9.6	1.4	15.7	0.1	1.0	6.0	4.0	15.7	0.2	8.1	66.7	16.8	48.5	24.8	26.7	scl
B21t	41-68	9.7	1.6	18.5	0.1	1.0	7.0	4.5	18.5	0.1	5.2	69.0	20.0	38.0	23.3	38.8	cl
B22t	68-105	9.6	1.7	19.5	0.1	2.5	6.0	3.0	12.3	0.2	9.5	58.5	21.2	35.9	29.7	34.5	cl
B23k	105-156	9.8	1.8	22.0	0.1	4.5	10.0	8.5	10.3	0.1	14.5	65.8	22.0	36.8	35.5	27.7	1

Verma *et al.* (2007) GW= Ground water

Table 2. Quality of water samples in Kurukshetra district

S N	Water sample (tubewells)- Location and depth	pH_{iw}	EC_{iw} ($dS\ m^{-1}$)	Na^+	K^+	$Ca^{2+}+Mg^{2+}$	CO_3^{--}	HCO_3^-	Cl^-	RSC	SAR ($me\ L^{-1})^{1/2}$
				($me\ L^{-1}$)							
1	Village Macheri (270 ft)	8.8	1.4	13.9	0.1	2.5	2.0	13.2	1.7	12.7	12.4
2	Village Macheri, (150 ft)	8.7	1.1	9.9	0.2	2.5	1.5	10.0	1.7	9.0	8.9
3	Village Seonsar (270 ft)	9.5	1.4	13.3	0.1	2.0	3.0	11.0	1.7	12.0	13.3
4	Village Kheri Daban (250ft)	9.1	1.3	12.6	0.1	1.5	Tr.	2.5	10.0	6.4	14.5
5	Village Hansu Majra (250 ft)	9.3	1.4	14.0	0.1	1.0	Tr.	3.0	6.0	2.0	19.7
6	Village Tatiana (300 ft)	9.1	1.6	16.6	0.1	1.0	0.0	3.0	5.0	2.0	23.4

to clay illuviation. The silt and clay contents were higher than sand content in P3 and P4 possibly due to lower topographic position.

The pHs values ranged from 9.1 to 10.7 showing slight to strong alkaline nature (Table 1) The ECe values in P2 (1.2 to 8.5 $dS\ m^{-1}$) and P1 (4.5 to 7.4 $dS\ m^{-1}$) is higher than P4 (1.2 to 1.8 $dS\ m^{-1}$) and P3 (2.4 to 6.6 $dS\ m^{-1}$) possibly due different land uses. The depth-wise increase of pHs values is found in all the pedons. The higher alkalinity (pHs 10.2) at sub-surface depth (>40cm) in P3 caused unfavorable physical properties and waterlogging. The higher pHs in P1 (9.6 to 10.2) and P2 (9.8 to 10.7) limited its use for arable cropping.

The ionic composition of soils showed the dominance of CO_3^{2-}+ HCO_3^- anions. It is high in P1 (17.0 to 28.5 me L^{-1}) and P2 (15.7 to 35.5 me L^{-1}) and low in P3 (5.0 to 15.5 me L^{-1}) and P4 (5.0 to 10.0 me L^{-1}). High Na^+ content in P1 (70.4 to 98.7 me L^{-1}), P3 (28.6 to 99.5 me L^{-1}), P2 (11.5 to 75.4 me L^{-1}) and P4 (13.3 to 22.0 me L^{-1}), indicated the presence of sodium carbonate and bicarbonate parent materials (Bhargava *et al.,* 1980, Sharma *et al.,* 2011). The low contents of Ca^{2+}+Mg^{2+} showed precipitation in alkaline medium (Bhargava and Bhattacharjee, 1982). The higher clay contents in P4 (24.8 to 38.8%) and P3 (23.4 to 28.0%) and at sub-surface layers of P1 (13.7 to 22.6%), P2 (18.0 to 25.0%) impaired drainage and favored waterlogging. Significant contents of $CaCO_3$ (*calcretes*) at 99 cm and 105 cm depths in P2 (1.3 to 4.9%) and P4 (4.4 to 14.5%) also enhanced drainage congestion and low permeability. The CEC values were low in P1 (8.8 to 13.1 cmol (p+) kg^{-1}) and P3 (13.2 to 18.4 cmol (p+) kg^{-1}) due to coarse texture and the presence of non-expanding minerals or mixed mineralogy. Higher CEC values in P2 (21.0 to 26.3 cmol (p+) kg^{-1}) and P4 (16.8 to 22.0 cmol (p+) kg^{-1}) is due to higher clay content. The high ESP values in P1 (49.6 to 76.9), P3 (50.0 to 94.6), P2 (46.8 to 56.5) and P4 (53.1 to 69.0) showed significant saturation with exchangeable Na^+.

The chemical properties of water samples showed high pH (8.7 to 9.5), RSC (9.0 to 12.7me L^{-1}), and SAR (12.4 to 23.4) that showed sodic character (Table 2). The salt composition showed dominance of CO_3^{2-} (1.5 to 3.0 me L^{-1}), HCO_3^- (2.5 to 13.2 me L^{-1}) and Na^+ (9.9 to 16.6 me L^{-1}) while Ca^{2+}+Mg^{2+} (1.0 to 2.5 me L^{-1}) and Cl^- (1.7 10.0 me L^{-1}) are also present. These samples with high RSC (SN 1 to 3) should be used after treatment with gypsum. The samples with moderate alkalinity (SN 4-6) can be used for the growing salt resistant varieties. Due to alkaline nature, gypsum treatment of water is needed for growing other crops.

Reclamation and Use Potential of Salt Affected Soils

Sodic soils of the Gangetic plain in Central Haryana are rich in sodium carbonate and bicarbonate salts and showed high ESP and variable soil texture. Strongly sodic soils (P1 and P2) containing high Na_2CO_3 and $NaHCO_3$ salts and coarse soil texture with sodic ground water needs gypsum application @ 8-10 t ha^{-1} to reduce alkalinity in soil and water followed by leaching of excess soluble salts. Moderately sodic soil (P3) containing soluble Na_2CO_3 and $NaHCO_3$ salts and fine soil texture can be reclaimed by addition of 4-6 t ha^{-1} gypsum. Due to high clay content and presence of $CaCO_3$ concretions, P4 (slightly sodic soil) showed drainage congestions and waterlogging. It may be used for growing rice (salt tolerant variety) and resistant wheat varieties for alkalinity and waterlogging. The addition of FYM and Dhaincha (*Sesbania* sp.) cultivation is also suggested to improve physical properties, drainage conditions and reduce waterlogging.

Conclusions

Visual interpretation of IRS data on 1:50,000 scale facilitated delineation salt affected soils and waterlogged areas the Gangetic plain of Central Haryana covering Kurukshetra district. The presence of strong alkaline salts (Na_2CO_3 and $NaHCO_3$), lack of natural drainage and waterlogging conditions in sodic soils caused low productivity. The high soil pHs, fine soil texture and presence of concretionary calcium carbonate layer at sub-surface depths are primary constraints for arable cropping. Suitable reclamation measures were suggested for strongly and moderately sodic soils using appropriate amendments such as gypsum or pyrite. Management options were also suggested for slightly sodic soil.

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References

Abrol, I. P. and Bhumbla, D. R. 1971. Saline and Alkali Soils in India-their Occurrence and Management. World Soil Resources Report No. **41**: Food and Agriculture Organization of United Nations, p 42-51

Bhargava, G. P., Sharma, R. C., Pal, D. K. and Abrol, I. P. 1980. A case study of distribution and formation of salt affected soils in Haryana state. (In) Proc. International Symposium on *Salt Affected Soils*, CSSRI, Karnal, pp. 83-90.

Bhargava, G. P. and Bhattacharjee, J. C. 1982. Morphology, Genesis and Classification of Salt Affected Soils. In "*Review of Soil Research of India*" Proceedings of the International Congress of Soil Science, 8-16 February, 1982, New Delhi, India, pp. 508-528

Gupta, S. K. 2010. *Management of Alkali Water*. Central Soil Salinity Research Institute, Karnal, India. Technical Bulletin: CSSRI/Karnal/2010/01, p62.

Jackson, M.L. 1986. *Advanced Soil Chemical Analysis*. Prentice Hall of India, New Delhi.

Manchanda, H.R. 1976. *Quality of Ground Waters in Haryana*. Haryana Agriculture University, Hisar, p. 160.

Manchanda, M. L. and Iyer, H. S. 1983. Use of Landsat imagery and aerial photographs for delineation and categorization of salt-affected soils of part of North-West India. *Journal of the Indian Society of Soil Science* **31,** 263-71

National Remote Sensing Agency 1997. *Salt Affected Soils*. National Remote Sensing Agency, Department of Space, Government of India, Hyderabad.

Richards, L. A. (Ed.) 1954. *Diagnosis and Improvement of Saline and Alkali Soils*. Agriculture Handbook No. 60 United States Department of Agriculture, Washington D. C.

Sharma, R. C., Mandal, A. K., Singh Ranbir, Singh, Y. P. 2011. Characteristics and use potential of sodic and associated soils in CSSRI experimental farm, Lucknow, Uttar Pradesh. *Journal of the Indian Society of Soil Science* **59**, 381-387.

Singh, G. B. 2009. Salinity related desertification and management strategies: Indian Experience *Land Degradation and Development* **20**, 367-385.

Soil Survey Division Staff 2004. *Soil Survey Manual*. United States Department of Agriculture Handbook No.18. Scientific Publishers (India) Jodhpur.

Soil Survey Staff 1998. '*Keys to Soil Taxonomy*', Eighth Edition, U.S. Soil Conservation Service, Washington, D. C.

Tanwar, B. S. 1996. '*Waterlogging and Salinization in India-Remedial Measures*'. In Proceedings of the Workshop "*Waterlogging and Soil Salinity in Irrigated Agriculture*" Verma, C. V. J. (Ed.), held on 12-15 March, 1996, CSSRI Karnal, p 1-19.

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Effect of saline and alkali water irrigation on physical and chemical properties of sodic clay loam soil

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ABSTRACT

Presence of appreciable amount of soluble salts has a deleterious impact for raising salinity/ alkalinity in semiarid and arid regions. We evaluated the effect of varying saline and alkali waters on physical and chemical properties of alkali soil which has characteristics of soil pH of saturation paste, electrical conductivity of saturation extract and exchangeable sodium percentage (ESP) of 8.75, 4.98 dSm^{-1}, 31.2%. Soil were sequentially leached in a constant head method using 1 litre volumetric flask and cores with normal (T_1), saline water at 5.0 (T_2) and 50.0 (T_3) me L^{-1} of total electrolyte concentration (TEC) at a fixed SAR of 2.5 $mmol^{1/2}\ L^{-1/2}$ with Ca:Mg ratio of 2:1, alkali water having residual sodium carbonate (RSC) of 1.0 (T_4) and 5.0 (T_5) me L^{-1} with Ca:Mg ratio of 2:1, respectively. Incoming solution of concentrated saline water (T_3) has a favourable influence for upkeeping soil hydraulic properties among the simulated saline and alkali water. Increase and decrease in pH_2 of soil water suspension revealed that both Ca^{2+} and Mg^{2+} build up and displace from exchange sites due to continuous application of normal and saline water, respectively. Residual carbonate and bicarbonate loading in incoming water aggravated alkalinity build up in soil when it was percolated with RSC water with varied quality. Abundance of HCO_3^- and CO_3^{2-} in alkali water caused the complete precipitation of the divalent Ca^{2+} and Mg^{2+} and increased the ESP to very high values.

Key words: *Alkalinity, residual sodium carbonate and bicarbonate, total electrolyte concentration*

Introduction

It is noteworthy that soil salinity is the most widespread problem in irrigated arid and semi-arid regions of the world where irrigation is essential to increase agricultural production to satisfy food requirements (Abrol *et al.,* 1988). Coupled with this, presence of soluble sodium carbonates and bicarbonates, abundant exchangeable sodium in water has a deleterious impact for raising salinity/ alkalinity in semiarid and arid regions (Pal *et al*., 2003; Dasberg *et al*., 1991). Salt stress imposes limits on plant growth and development by causing physiological abnormalities. Food production is severely affected due to increase in area under salinization and decrease in overall productivity of good and fertile soils as a result of improper irrigation and water management practices (IAEA, 1995). Even at low salt concentrations, there are widespread direct and indirect harmful effects (Shannon *et al*., 1994). The degree of adverse effects depends upon the type and quantity of salts, soil texture, type of crop, variety, stage of growth, cultural practices, and environmental factors (temperature, relative humidity, and rainfall) (Chhabra, 2005). The burgeoning world population has put tremendous pressure on food supplies from the scarce land and water resources. This situation demands effective management of degraded salt-affected lands and poor quality waters. Soils of the Indo-Gangetic plains are of alluvial origin but at some places Aeolian processes are still running. Cultivation of these fertile landscape was compelled to irrigate with alkali/ saline underground water containing a high amount (>2.5 mol m^{-3}) of residual sodium carbonate (RSC) which leads to precipitation of soluble Ca^{2+} as $CaCO_3$ and thus increases SAR (Chhabra, 2005). Historically, based on pH of the saturated paste, electrolytic conductivity of the saturated paste extract (EC_e), and exchangeable sodium percentage (ESP), the U.S. Salinity Laboratory (Richards, 1954) classified these soils into three categories, *viz.*, saline, alkali and saline-alkali. Excess of soluble salts and high exchangeable sodium are main feature of saline-alkali soil. High in pH_s (>8.5) and ESP (>15%) and EC_e being ~4 dS m^{-1} are the characteristics of alkali soil. Some advanced attempts had been made by a number of researchers for distinguishing alkali soil from others salt affected soils. These are: dominance of Na^+ as cation and CO_3^{2-} +HCO_3^- in saturation extract (Chhabra, 2005); or the ration of $[Na^+]/([Cl^-] + [SO_4^{2-}])$ in soil solution more than 1.0 (Bajwa and Swarup, 2009). Formation of alkali soils may involve microbiological reduction of sulfate and ferric iron to form sulphide (FeS), which with CO_2 released by biological oxidation of abundant organic matter forms bicarbonate (Whittig and Janitzky, 1963). Small amounts of soluble carbonate compared with bicarbonate suggest that, because of high evaporation rates, and maintenance of a proper Ca/Mg ratio in the soil solution becomes difficult because Ca^{2+} ions are precipitated as $CaCO_3$. The soil solution consequently becomes impoverished in Ca^{2+} ions and this causes an increase in SAR and ESP. Thus, concomitant formation of $CaCO_3$ and development of alkaliity (Pal *et al.*, 2000, 2001) account for the abundance of soluble Na^+ ions and the calcareousness of the soils. The sodium adsorption ratio (SAR) has frequently been used to characterize the clogging hazard of irrigation water based on the composition of sodium relative to calcium and magnesium (Ayers and Westcot, 1989). The SAR value reflects the preference of soils to adsorb calcium and magnesium ions over sodium ions and is correlated with the degree of sodium saturation on the exchange sites. Reduced soil permeability with higher SAR solutions has been well documented in the literature (Suarez *et al.,* 2006). Because of high pH, soil organic matter gets dissolved and forms black organic-clay coatings on soil aggregates and on the surface giving the term black-alkali for such soils. Growing plant faces adverse effects not only due to high ESP but also due to high pH and associated poor physical properties like of such low hydraulic conductivities and degraded in soil structure (Mandal *et al.*, 2008). Irrigation with water of moderate SAR (~6 $mmol^{1/2} l^{-1/2}$) leads to an exchangeable sodium percentage (ESP) of a comparable value in the soil and adversely affects on soil hydraulic conductivity (HC), due to Na^+-induced clay dispersion (Halliwell *et al.*, 2001). Usually, it is observed that the hydraulic conductivity of soils decreases with an increase in SAR and effects are more pronounced at low electrolyte concentrations (Girdhar, 1996). However, Gharaibeh *et al*, 2009, claimed that high electrolyte concentration in leaching water increases the hydraulic conductivity; this effect is amplified as the ESP of the soil being reduced in sandy clay loam, mixed, hyperthermic, Typic Xerochrept soil. Quirk, 2001 concluded that the use of concentrated solutions for reclamation of alkali soils of high ESP saves time and water. Keeping all this in mind the main approaches of this paper is to evaluate the performances of different poor quality water on the chemical and hydraulic properties of the soil.

Material and Methods

Bulk soil sample was collected from upper 30 cm depth of A or Ap horizon of clay loam soil of Krishi Vigyan Kendra (29°45.775'N, 76°24.550'E) of Chaudhary Charan Singh Harayana Agricultural University, Kaithal, Haryana India. Soil pH_s 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 (Mhor's) titration as described by Jackson, 1973. Carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) were determined by methyl red and phenolphthalein end point titration.

Dry soil sample (<2 mm) was packed to a bulk density of 1.25 g cm^{-3} upto 7-cm in cores. The soil cores were slowly wetted from the bottom by capillary rise with deionized water (EC < 1.0 dS m^{-1}) for 24-h or until the water reached the soil surface. Saturated hydraulic conductivity (Ks) of soils was determined by constant head method using 1 litre volumetric flask and cores. Soil-filled rings, after tightening inside the ring-holders, were transferred to the hydraulic conductivity stand. The different quality waters, *viz.*, normal (tap water EC < 1.0 dS m^{-1}) (T_1), dilute saline water (TEC 5.0 me L^{-1} and SAR 2.5 $mmol^{1/2} L^{-1/2}$) (T_2), concentrated saline water (TEC 50.0 me L^{-1} and SAR 2.5 $mmol^{1/2} L^{-1/2}$) (T_3), dilute alkali water (RSC 1.0 me L^{-1}) (T_4) and concentrated alkali water (RSC 5.0 me L^{-1}) (T_5) were used for hydraulic conductivity experiment by passing through the soil. Pure chloride salts of calcium, magnesium and sodium at Mg:Ca = 1:2 were used to prepare different saline water quality combinations whereas, chloride salts of calcium and magnesium and bicarbonate salt of sodium at Mg : Ca = 1:2 were used to prepare different alkali water quality combinations. Soil samples were then saturated for 12-hours inside the container. By fixing the volumetric flask, maintained constant head in inner water level in the core. Hydraulic head was precisely measured and the flow rate periodically recorded until the steady state reached. Procedure followed for Ks determination was similar to that described by Klute and Dirkson (1986). All the determinations were repeated three times to reduce the experimental error. Ks was calculated by rearranging Darcy's equation for constant head determination as:

$$Ks = \frac{V.L}{A.t.H}$$

Where,

V = Volume of water at steady state in mL

L = Length of the soil samples in cm

A = Cross sectional area of the soil sample in cm^2

T = Time in hour and

H = Hydraulic head difference in cm

Ionic consumption of each saline quality waters was computed as follows-

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}} \quad \ldots(1)$$

Now, if SAR = A and TEC = $Na^+ + Ca^{2+} + Mg^{2+}$ = B

or, $Ca^{2+} + Mg^{2+} = B - Na^+$

SAR can be re-written as:

$$A = \frac{Na^+}{\sqrt{\frac{B - Na^+}{2}}} \quad \ldots(2)$$

$$\text{or, } \frac{\left(B - Na^+\right)}{2} = \frac{\left(Na^+\right)^2}{A^2}$$

rearranging in a quadratic equation

$$2(Na^+)^2 + A^2Na^+ - A^2B = 0 \quad \ldots(2)$$

$$\text{and hence, } Na^+ = \frac{-A^2 \pm \sqrt{A^2 + 8A^2B}}{4}$$

$$\text{or, } Na^+ = \frac{\left[\sqrt{8B + A^2} - A\right]}{4}\text{, me L}^{-1}$$

if Na^+ (me L^{-1}) = x, then

$Ca^{2+} + Mg^{2+}$ (me L^{-1}) = B – x

but Ca:Mg = 2:1, and therefore

Ca^{2+} (me L^{-1}) = [(B-x)×2]/3

and Mg^{2+} (me L^{-1}) = B – ($Na^+ + Ca^{2+}$)

First effluents, corresponding to the pore volume, were discarded. After appearing steady state water flow volume of effluent solution was measured at 2-h interval for getting the saturated hydraylic conductivity. At the end of saturated hydraulic conductivity experiment, soil cores were left to drain free, then cut it to dry. Soil samples of different cores were analysed for EC, pH and exchangeable Na^+, Ca^{2+} and Mg^{2+} and anion CO_3^{2-}, HCO_3- and Cl^- and ESP.

Results and Discussion

Selected soil properties

Basic physico-chemical properties of experimental soil paste extract are presented in Table 3. Soil pH is considered the single most important chemical property of soil because it governs most of the soil processes including the concentration of Ca^{2+}, Mg^{2+}, Na^+ as well as Al^{3+} availability in soil (Panda *et al.*, 2009; Bajwa and Swarup, 2009). The pH_s was 8.75 in saturation paste extract. Electrical conductivity (EC_2) of experimental soil was 0.98 and 4.98 dSm^{-1} in soil water suspension and soil water saturation paste extract, respectively. Exchangeable sodium which one of important properties for differentiating boundary between saline and alkali soil can also exerts an adverse effect on the soil physical properties. Our finding showed that the experimental soils were alkali in nature as pH_2 is 8.7, EC_e 4.98 dSm^{-1} and ESP 31.2%. Soil organic carbon was found high (i.e. 0.86 %). Cation exchange capacity (CEC) can be used as an indicator of the potential fertility and nutrient supply capacity and a guide to methods of fertilizer application for efficient utilization by crops for better crop responses. CEC of a soil depends largely on amount and type of clay besides the organic matter content. The CEC of the soil was 13.54 $cmol_{(P+)}$ kg^{-1}. The relative proportion of sand, silt and clay content of the experimental soil was 44.3, 24.0 and 31.8, respectively. These indicated that the soil was clay loam in texture with good amount of clay.

Cations and anions in saturation paste extract

The Na^+ concentration in saturation extract of saline was almost 4.3- and 7.8-times higher than Ca^{2+} and Mg^{2+}, respectively (Table 3). Dominant Na^+ concentration in soil saturation paste was preveously reported by Chhabra,

Table 1. Chemical composition of saline waters

Total electrolyte concentration(me L^{-1})	Ca/Mg ratio	Ionic composition at SAR (2.5 $mmol^{1/2}$ $L^{-1/2}$)		
		Na^+	Ca^{2+}	Mg^{2+}
T_2: Dilute saline waters 5.0	2:1	0.157	0.114	0.078
T_3: Concentrate saline waters 50.0	2:1	0.645	2.884	2.641

Whereas, Ionic consumption of each alkali quality waters was computed as follows-

RSC = (CO_3+HCO_3) - (Ca+Mg)

Table 2. Chemical composition of alkali waters

Residual sodium carbonate(me L^{-1})	Ca/Mg ratio	Na^+	Ca^{2+}	Mg^{2+}
T_4: Dilute alkali waters 1.0	2:1	0.157	0.114	0.078
T_5: Concentrate alkali water 5.0	2:1	0.645	2.884	2.641

Table 3. Physico-chemical properties of the experimental soils

pH_s		8.75
EC_2	dS m^{-1}	0.98
ECe		4.98
Cation exchange capacity	$cmol_{(P+)}$ kg^{-1}	13.54
Exchangeable sodium percentage	%	31.2
$CaCO_3$		1.3
Organic C		0.86
Sand		44.3
Silt		24.0
Clay		31.8
Texture		Clay loam

Table 4. Ionic composition (me L^{-1}) of saturation extract of the experimental soils

Ca^{2+}	18.1
Mg^{2+}	10.0
Na^+	78.17
K^+	0.25
Cl^-	21.6
CO_3^{2-}	nil
HCO_3^-	14.0

1996 under a wide range of alkali soils. Increasing soil alkalinity always manifests the limited uptake of Ca by plant as the antagonistic effect between Na and Ca are persist in soil water solution. The saturation extract of experiment soil contained measurable amounts of HCO_3^- and Cl^- but CO_3^{2-} was non detectable (Table 4).

Effect of normal and synthetic water on soil hydraulic conductivity (Ks):

Hydraulic-conductivity plays an important role in computing the soil-water balance and salt, nutrient, and pesticide dynamics in the soil (Chaudhari *et al.*, 2010). Saturated hydraulic conductivity of soil was greatly influenced by the quality of water *viz.*, normal (tap water EC < 1.0 dS m^{-1}) (T_1), dilute saline water (TEC 5.0 me L^{-1} and SAR 2.5 $mmol^{1/2}$ $L^{-1/2}$) (T_2), concentrated saline water (TEC 50.0 me L^{-1} and SAR 2.5 $mmol^{1/2}$ $L^{-1/2}$) (T_3), dilute alkali water (RSC 1.0 me L^{-1}) (T_4) and concentrated alkali water (5.0 me L^{-1}) (T_5) flowing through the soils (Fig. 1). Low Ks value (0.002 cmh^{-1}) was recorded when soil core was percolated with normal tap water. Incoming solution of concentrated saline water sharply enhanced Ks value i.e. 0.016 cm h^{-1}. However, percolating dilute saline water failed to enhance Ks value. Soil Ks value increased 4 and 2.4- times when fed with dilute alkali water (RSC 1.0 me L^{-1}) (T_4) and concentrated alkali water (5.0 me L^{-1}). This indicates that concentrate alkali water is not very effective in reclaiming highly alkali soils. Irrigated with concentrated saline water has a favourable influence for upkeeping soil hydraulic properties among the simulated water quality levels.

Effect of normal and synthetic water on pH_2 and EC_2

Results showed that the experimental soils become more alkaline by percolating normal tap water (Fig. 2). Due to continuous feeding with normal tap water, the

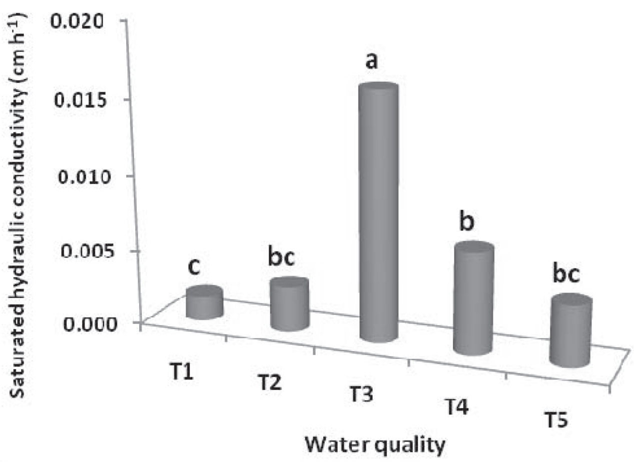

Fig. 1. Effect of different water quality on saturated hydraulic conductivity (Ks). (Different small letters within the same column show the significant difference at P = 0.05 according to Duncan Multiple Range Test (DMRT) for separation of mean)

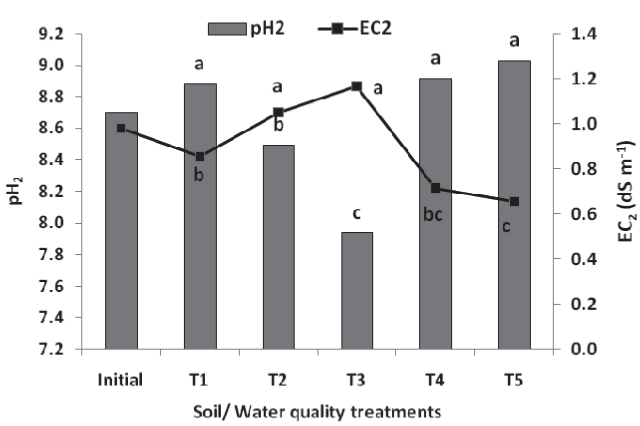

Fig. 2. Effect of different water quality on pH_2 and EC_2. (Different small letters within the same column show the significant difference at P = 0.05 according to Duncan Multiple Range Test (DMRT) for separation of mean)

soils might undergo in physic-chemical transformations, which are reflected in terms of variation in pH. However, pH_2 increase with the rapid displacement of Ca^{2+} and Mg^{2+} compared to Na^+ from exchange sites. A similar increased in pH of soil effluent was recorded both by Basak (2012) in response to the feeding the soils with deionized water in both saline-alkali and alkali soil. The pH_2 of the soil drastically declined from 8.70 to 7.94 when soil was fed with concentrate saline water. However, this decrease in soil pH_2 might be due to enrichment of exchange phase of soils by Ca^{2+} and Mg^{2+} which was abundant in incoming solution of concentrated saline water with low SAR. This was explained by Rai, 2012 who speculated that loaded salt moderate the dispersing action of Na^+ and no further deterioration of soil structure is quite restricted. Minimum decrease in soil pH_2 was reported when soil was leached with dilute saline water. The possible reason behind this may be due to incoming solution had a low Ca^{2+} and Mg^{2+} loading with fixed SAR of 2.5. Soils pH_2 become more alkali from 8.70 to 8.92 and 9.03 when it was fed with carbonate rich water of RSC 1.0 and 5.0 meL^{-1}, respectedly. Residual carbonate and bicarbonate loading in incoming water aggravated alkalinity build up in soil when it was percolated with RSC water. Choudhary et al., 2011 reported that long-term irrigation with alkali water with RSC of 10.0 $mmol_c$ L^{-1} from 1991-1999 and of 12.5 $mmol_c$ L^{-1} from 2000 onwards raises soil pH to 10.04 from 7.9 in a calcareous sandy loam soil in rice-wheat system at Ludhiana.

The graphical representation of EC_2 did not find similar signature as that of pH_2 (Fig 2). EC_2 of soil water suspension decreased when tap water was used as incoming solution. Dissolution followed by leaching of soluble salt from exchange site may help to reduce soil EC_2. A similar decrease in EC_2 of soil was recorded both by Basak (2012) and Rai (2012) in response to the percolation of soil with deionized water in alkali and saline-alkali soil. A significant increase in EC_2 was noticed in soil water suspension when soil was feeding with concentrated saline water compared to dilute saline water. The existence of cations (Ca^{2+}, Mg^{2+} and Na^+) and anion ($Cl^{''}$) in incoming solution may increase EC_2 (Minhas and Bajwa, 2001; Choudhary *et al.*, 2004; Jalali and Ranjbar, 2009). Decline in the EC_2 under different treatments of studied soil with increment of pH_2 are described in Fig. 3. However, long-term application of alkali irrigation in rice-wheat system raised 1.67 dS m^{-1} unit in EC_2 along with pH_2 (Choudhary *et al.*, 2011).

Effect of normal and synthetic water on cations and anions

The soil solution of a saline alkali soil mainly contains cations *viz.*, Na^+, Ca^+, Mg^{2+} and K^+ and anions like Cl^-, SO_4^{2-}, HCO_3^-, CO_3^{2-} & NO_3^-. All the cations and anions studied in soil water extract. Soil water extract of initial soil sample had 10.6 times higher values of the Na^+

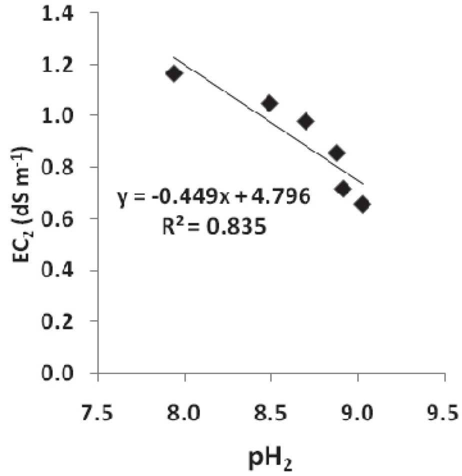

Fig. 3. Relationship between pH_2 and EC_2 under different treatments of studied soils

compared to Ca^{2+}, Mg^{2+} and 5- times higher values of Cl^- compared to HCO_3^-, CO_3^2. As soils were saline alkali in nature, Na^+ was dominant amongst all the cations and Cl^- amongst anions (Table 5). Alkalinity of experimental soil had been inclining towards more alkaline by leaching appreciable amount of soluble and exchangeable amount of Na^+ (~68%) from soil when it was fed with normal water. Incidentally, CO_3^{2-}+HCO_3^- build up was noticed when soil was percolated with concentrated alkali water (5.61 meL^{-1}) compared to normal water (0.64 meL^{-1}). This value was previously corroborated in pH_2, EC_2 and ESP values of untreated and normal water percolated soil. This shows that ~10.0 fold change in alkalinity (CO_3^{2-}+HCO_3^-) has a dominative effect than ~68% reduction of Na^+ concentration for unit changing in pH (Bajwa and Swarup, 2009). However, our study not match with Eaton and Sokoloff (1935) who reported that alkali soils are formed due to leaching of soluble salts, particularly Ca^{2+} and Mg^{2+} and subsequent replacement by sodium. Concentrated saline water leached out good amount of Na^+ and CO_3^{2-}+HCO_3^- *vis-a-vis* increased the concentration of Ca^{2+}+ Mg^{2+} in exchange sites. However, dilute saline water was able to leach an appreciable amount of Na^+ but totally in vain to leach CO_3^{2-}+HCO_3^-. Moreover, it sustained alkalinity of 5.71 meL^{-1} (CO_3^{2-} +HCO_3^-). Alkalinity was built-up was noticed by application of both dilute and concentrate alkali water. However, content Na^+ and alkalinity was higher in soil water solution when it was percolated with concentrated alkali water compared to dilute alkali water. Irrespective of water quality, leaching loss of Cl^- was higher from exchange sites to solution at dilute TEC level than the lower TEC level. However, Cl- built-up was noticed when it was fed with concentrate saline was except in normal Vertisols. An appreciable and minimum quantity of Cl^- was detected in soil water extract when it was fed with concentrate saline and dilutes alkali water, respectively.

Table 5. Ionic composition and $CaCO_3$ of soil water solution extract of the experimental soils under varied treatment

Soil/ Treatment	Na^+	K^+	$Ca^{2+}+Mg^{2+}$	CO_3^{2-}	HCO_3^-	Cl^-	$CaCO_3$
	mel^{-1}						%
Normal tap water	13.18^a	1.41^a	2.00^{bc}	0.71^b	4.90^a	1.63^b	0.83^{ab}
Dilute saline water	11.82^{ab}	0.68^b	2.13^{bc}	0.78^b	4.93^a	2.17^b	0.83^{ab}
Concentrated saline water	10.42^{bc}	0.07^c	2.70^a	0.01^c	0.23^b	10.67^a	0.83^{ab}
Dilute alkali water	8.79^c	0.85^b	1.63^c	0.71^b	5.30^a	1.38^b	0.90^a
Concentrated alkali water	9.63^c	1.01^{ab}	2.40^{ab}	0.96^a	5.60^a	1.52^b	0.70^b
Mean	10.77	0.80	2.17	0.64	4.19	3.47	0.823
SE(±)	0.48	0.13	0.13	0.09	0.55	0.98	0.0446
Initial	20.15	0.92	1.90	1.2	0.2	7.0	1.30

(Different small letters within the same column show the significant difference at P = 0.05 according to Duncan Multiple Range Test (DMRT) for separation of mean)

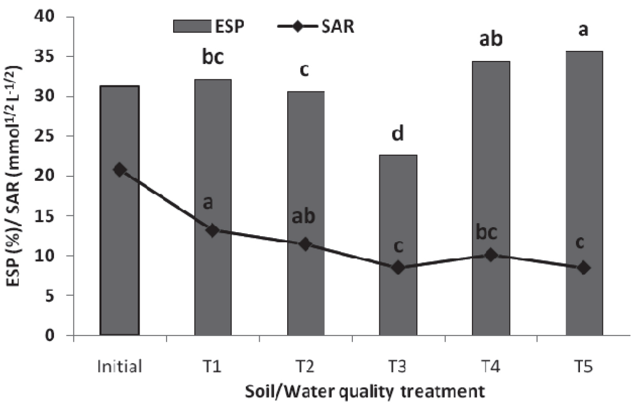

Fig. 4. Effect of different water quality on ESP and SAR. (Different small letters within the same column show the significant difference at P = 0.05 according to Duncan Multiple Range Test (DMRT) for separation of mean)

Effect of normal and synthetic water on ESP and SAR

High ESP value of salt affected soils is unfavourable to water availability by plant, soil hydraulic property, soil conservation, plant nutrient balance, and subsequently specific ionic effect (Qadir and Schubert, 2002), which hinders the development of sustainable irrigated agriculture (Li and Keren, 2008). The poor physical soil conditions accompanied with high soil pH make soil poor in stability. Salt concentrations of the soil solution affect clay and silt dispersion (Dontsova and Norton, 2002). The ESP and SAR value of initial soil was 31.2% and 20.8 mmol$^{1/2}$ L$^{-1/2}$. Leaching with normal tap water had the marginal disparity in ESP built-up but reduced SAR. Predicting the marginal ESP built-up in clay loam soil with CEC of 13.54 cmol$_{(P+)}$ kg^{-1} was not clear and we need further extensive work (Fig. 3). However, an appreciable amount of Na^+ was leached by percolation with normal tap water. The low SAR value of 20.8 mmol$^{1/2}$ L$^{-1/2}$ vividly depicted the remarkable higher losses of Na^+ than Ca^{2+} and Mg^{2+}. When SAR increases, the rate of the soil sodification process also increases (Herrero and Perez Covetta, 2005). Alkalinity enhances deterioration of the hydraulic properties of soils, which could increase the possibility of surface runoff and erosion, and impair soil drainage (Keren and Ben-Hur, 2003). The experimental ESP built-up was lowest when soil fed with dilute saline water compared to concentrated saline water with fixed SAR of 2.5 mmol$^{1/2}$ L$^{-1/2}$. As the lower volume of solution was percolated associated with low Ks (0.002 cmh^{-1}), higher the development of ESP (Chaudhari, 2004). During leaching, presence of higher amount of Ca^{2+} and Mg^{2+} in concentrate saline water may maintained Ca^{2+} and Mg^{2+} in solution phase and displaced and followed by leached the Na^+ and decreased SAR. Percolation with both dilute and concentrated alkali water caused an ESP built-up. Contrarily, decline the SAR form initial soil value. Excess of HCO_3^- and CO_3^{2-} caused the complete precipitation of the divalent Ca^{2+} and Mg^{2+} and increased the ESP to very high values (Eaton et al., 1950). The magnitude of Na^+ in soil is quantified by the exchangeable sodium percentage or by its estimator, the sodium adsorption ratio SAR.

Conclusions

Incoming solution of concentrated saline water has a favourable influence for upkeeping soil hydraulic properties among the simulated saline and alkali water. Increase and decrease in pH_2 of soil water suspension revealed that both Ca^{2+} and Mg^{2+} build up and displacement from exchange sites may possible due to continuous application of tap water and saline water. Residual carbonate and bicarbonate loading in incoming water aggravated alkalinity build up in soil when it was percolated with RSC water with varied quality. Abundance of HCO_3^- and CO_3^{2-} in alkali water caused the complete precipitation of the divalent Ca^{2+} and Mg^{2+} and increased the ESP to very high values.

References

Abrol, I.P., Yadav, J.S.P. and Massoud, F.I. 1988. Salt-affected soils and their management. FAO Soils Bulletin 39, Food and Agriculture Organization of the United Nations Rome, Italy.

Ayers, R.S. and Westcot, D.W. 1989. Water quality for agriculture. FAO Irrigation and Drainage Paper 29 Rev. 1. FAO, Rome.

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

Basak, N. 2012. Impact of Varying Ca : Mg Waters on Ionic Balance, Dispersion and Clay Flocculation of Salt Affected Soils. Abstract Published on National Seminar on Development of Soil Science. Indian Society of Soil Science. Dec. 3-6, 2012, Punjab Agricultural University, Ludhiana.

Chaudhari, S.K. and Somawanshi, R.B. 2004. Unsaturated flow of different quality irrigation waters through clay, clay loam and silt loam soils and its dependence on soil and solution parameters. *Agricultural Water Management* **64**: 69-90.

Chaudhari, S.K., Singh, R. and Kumar, A. 2010. Suitability of a hydraulic-conductivity model for predicting salt effects on swelling soils. *Journal of Plant Nutrition and Soil Science* **173:** 360–367.

Chhabra, R. 2005. Classification of Salt-Affected Soils. *Arid Land Research and Management* **19:** 61–79, 2005.

Chhabra, R.1996. *Soil Salinity and Water Quality*. Oxford & IBH Publishing Co. Pvt. Ltd. New Delhi.

Choudhary, O.P., Ghuman, B.S., Bijay-Singh, Thuy, N. and Buresh, R.J. 2011. Effects of long-term use of sodic water irrigation, amendments and crop residues on soil properties and crop yields in rice–wheat cropping system in a calcareous soil. *Field Crops Research* **121:** 363–372.

Dasberg, S., Bielorai, H., Haimowitz, A. and Erner, Y. 1991. The effect of saline irrigation water on "Shamouti" orange trees. *Irrigation Science* **12**: 205-211.

Dontsova, K.M. and Norton, L.D. 2002. Clay dispersion, infiltration and erosion as influenced by exchangeable Ca and Mg. *Soil Science* **167(3)**: 184-193.

Eaton, F.M.1950. Significance of carbonates in irrigation waters. *Soil Science* **69**: 123-133.

Gharaibeh, M.A., Eltaif, N.I. and Shunnar, O.F. 2009. Leaching and reclamation of calcareous saline-alkali soil by moderately saline and moderate-SAR water using gypsum and calcium chloride. *Journal of Plant Nutition and Soil Science* **172**: 713–719.

Girdhar, I.K. 1996. Effect of leaching with waters of varying RSC, SAR and electrolyte concentration on properties of Haplustalf. *Journal of the Indian Society Soil Science* **44(3)**: 495-499.

Halliwell, D.J., Barlow, K.M. and Nash, D.M. 2001. A review of the effects of wastewater sodium on soil physical properties and their implications for irrigation systems. *Australin Journal Soil Research* **39**: 1259–1267.

Herrero, J. and Perez Covetta, O. 2005. Soil salinity changes over 24 years in a Mediterranean irrigated district. *Geoderma.* **125**: 287-308.

International Atomic Energy Egency. 1995. Management strategies to utilize salt-affected soils. IAEA-TECDOC-814. Vienna.

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.

Keren, R. and Ben-Hur, M. 2003. Interaction effects of clay swelling and dispersion and $CaCO_3$ content on saturated hydraulic conductivity. *Australian Journal of Soil Research.* **41**: 979-989.

Klute, A. and Dirkson, C. 1986. Hydraulic Conductivity and Diffusivity: Laboratory Methods. In. Methods of Soil Analysis; Klute, A. (ed.), Part 1 *Agronomy Society of America*, Madison, WI, pp: 687-732.

Li, F. and Keren, R. 2008. Native $CaCO_3$ Mineral Dissolution and Its Contribution to Alkali Calcareous Soil Reclamation Under Laboratory Conditions. *Arid Land Research and Management* **22:** 1-15.

Mandal, U.K., Bhardwaj, A.K., Warrington, D.N., Goldstein, D., Tal, A. B. and Levy, G.J. 2008. Changes in soil hydraulic conductivity, runoff, and soil loss due to irrigation with different types of saline–alkali water. *Geoderma* **144**: 509–516.

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.

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

Pal, D.K., Balpande, S.S. and Srivastava, P. 2001. Polygenetic Vertisols of the Purna Valley of Central India. *Catena* **43**: 231–249.

Pal, D.K., Dasog, G.S., Vadivelu, S., Ahuja, R.L. and Bhattacharyya, T. 2000. Secondary calcium carbonate in soils of arid and semi-arid regions of India. In: Lal, R., Kimble, J.M., Eswaran, H. and Stewart, B.A. (Eds.), Global Climate Change and Pedogenic Carbonates. Lewis Publishers, Boca Raton, pp. 149-185.

Pal, D.K., Srivastava, P., Durge, S.L. and Bhattacharyya, T. 2003. Role of microtopography in the formation of alkali soils in the semi-arid part of the Indo-Gangetic Plains, India, *Catena* **51**: 3-31.

Panda, N., Sarkar, A.K. and Chamuah, G.C. 2009. Soil acidity In: *Fundamental of Soil Science*. Indian Society of Soil Science, IARI, New Delhi, pp. 317–328.

Qadir, M. and S. Schubert. 2002. Degradation processes and nutrient constraints in alkali soils. *Land Degradation & Development* **13**:275–294.

Quirk, J.P. 2001. The significant of the threshold and turbidity concentrations in relation to alkaliity and microstructure. *Australian Journal Soil Research* **39**: 1185–1287.

Rai, P. 2012. Hydrophysical behavior of waterlogged alkali soils under biodrainage. M. Sc. Thesis submitted to Veer Bahadur Singh Purvanch University, Jounpur, Uttar Pradesh. pp 1-72.

Richards, L.A. 1954. Diagnosis and Improvement of Saline Alkali Soils. USDA Handbook No. 60. Washington, DC, USA.

Schwartzenbach, G., Biedermann, W. and Bangerter, F. 1996. Komplexone VI. Meue einfache Titrimethoden zur Bestimmung der Wesserharte. *Helvetica Chimica Acta* **29**: 811-818.

Shannon, M.C., Grieve, C.M. and Francois L.E. 1994. Whole-plant response to salinity. In: Plant-Environment Interactions (Eds. Wilkinson RE). Marcel Dekker Inc. New York, pp. 199-244.

Soil Survey Staff. 1999. Soil Taxonomy–A Basic System of Soil Classification for Making and Interpreting Soil Surveys. Agriculture Handbook No. 436. 2nd Ed. U. S. Department of Agriculture. Natural Resources Conservation Service. Washington, DC, USA.

Suarez, D.L., Wood, J.D. and S.M. Lesch. 2006. Eff ect of SAR on water infi ltration under a sequential rain-irrigation management system. *Agricultural Water Management* **86**:150–164.

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 of Soil Research* **23**: 405–416.

US Salinity Laboratory Staff. 1954. Diagnosis and Improvement of Saline and Alkali Soils. Hand book 60. U.S. Department of Agriculture, Washington, D.C., USA.

Walkey, A. 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.

Whittig, L.D. and Janitzky, P. 1963. Mechanisms of formation of sodium carbonate in soils: I. Manifestation of biological conversions. *Journal Soil Science* **14**: 322–333.

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Economics of zero tillage and conventional methods of rice and wheat production in Haryana

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ABSTRACT

Adoption of zero tillage technology by farmers in India has occurred mainly in the rice-wheat crop production system. It was adopted primarily for the wheat crop. The spread of technology was rapid in the north-western states which are relatively better endowed with respect to irrigation, mechanization and relatively large size of land holdings. In India, widespread adoption of zero tillage method of cultivation was started in Haryana state. It is emerged as a way to achieve enhanced productivity and profitability while protecting natural resources and environment. In this study, an attempt has been made to analyze the comparative economics of zero tillage and conventional methods of rice and wheat cultivation in Haryana state. The study revealed that the net return was higher in zero tillage mainly due to reduction in operational cost by 14% than conventional method of rice cultivation. In case of wheat, both yield and net returns were significantly higher in zero tillage by 5.54% and 24.72%, respectively. The respective saving of human labour, machine labour and irrigation were 12.95%, 41.75% and 17.60% in rice production by zero tillage method. Similarly, use of human labour, machine labour and irrigation were saved by 13.93%, 45.88% and 15.98%, respectively in zero tillage than conventional method of wheat production. Zero tillage technology enabled farmers to increase returns and save crucial inputs cost. Hence, this technology promises to be an important alternative for generating higher farm income and saving of scarce resources in resource starved regions.

Key words: conventional tillage, resource conservation, rice and wheat production, zero tillage

Introduction

Zero tillage technology was adopted primarily for wheat crop mainly in rice-wheat crop production system in India. The spread of zero tillage technology was rapid in the north-western states which are relatively better endowed with respect to irrigation, mechanization and relatively large size of land holdings. The cost saving is the main driver behind its spread (Erenstein, 2009). This technology is emerged as a way to achieve enhanced productivity and profitability while protecting natural resources and environment in the Indo-Gangetic Plains of India. Rice-wheat is the major cropping system in this region. Major rice-wheat growing states in Indo-Gangetic Plains are Punjab, Haryana, Uttar Pradesh, Himachal Pradesh, Bihar, and West Bengal.

In India, widespread adoption of zero tillage method of cultivation was started in Haryana state. Resource conserving technologies such as zero tillage, surface seeding and raised bed in both rice and wheat have been found beneficial in terms of reducing cultivation cost and energy consumption and improving farmers income (Gupta and Seth, 2007). Savings in input cost, fuel consumption and irrigation water use have been reported due to zero tillage in wheat (Malik *et al.,* 2002, 2003, Bhushan *et al.,* 2007). Moreover, farmers in Haryana started zero tillage a decade back particularly in wheat and recently in rice due to rising fuel prices and labour shortage as inputs cost saving alternative to sustain the crop production. Zero tillage technology versus conventional methods of rice cultivation has not been evaluated widely in farmer's field. Hence, the present study was undertaken with the objective to compare the economics of zero tillage and conventional methods of rice and wheat cultivation in rice-wheat crop production system.

Material and methods

In an attempt to reduce the production costs and increase the total factor productivity, both state and central governments have taken several initiatives to popularize zero tillage technology. The Haryana state was selected purposively for this study as farmers are rapidly adopting zero tillage technology in rice and wheat cultivation. Karnal district was selected purposively due to widespread adoption of zero tillage method of cultivation. The mean annual rainfall of the area varies from 650 to 950 mm, about 80% of which is received during June to September. The soils are generally sandy loam to clay loam in texture and low to medium in organic matter content.

Groundwater and canal irrigation are main source of irrigation. The average temperature ranges from a minimum of 2.8°C in January to 45°C in May.

From Karnal district, three villages were selected for the study. The primary data were collected from 20 farmers who adopted zero tillage technology in rice. The equal numbers of farmers were selected for collection of primary data regarding conventional tillage of rice cultivation. Similar procedure was adopted for wheat production. Hence, primary data were collected during 2010-2011 from 80 farmers with the help of pre-tested interview schedule by survey method. Data were analyzed using partial budget technique, input-output ratio and percentage analysis.

The cost of cultivation was calculated by taking into account the cost of seed, fertilizers, pesticides, hiring charges of human labour and machine labour for land preparation, irrigation, fertilizer application, spraying of plant protection chemicals, harvesting, threshing, bagging and transportation to nearest market. Over-head costs include depreciation charges on equipments and interest on working capital. The cost of irrigation was calculated by multiplying the time required to irrigate the farm with cost of electricity or per hour diesel consumption. Electricity rates were as per state electricity boards. The cost human labour, machine labour and diesel cost were taken as actual expenditure incurred by farmers. Gross income was the total money received by farmers on the sale of crop output after deducting the transportation cost. Net income was calculated as the difference between gross income and total cost.

Results and discussion

Socio-economic features

Farmers in the study area grow crops and maintain livestock on their farms. The rice is grown during *kharif* season. In *rabi* season, wheat, mustard, vegetables and berseem are grown. The crop and livestock enterprises contribute 82% and 5%, respectively, to the total household income. Many farmers supplement their household income by engaging themselves or their family members in off farm activities. The average age of respondent farmers was in the range of 34-41 years, indicating that they were relatively young age group. Farmers have 10-15 years of farm experience in farming. The size of land holdings was in the range of 2-10 hectares, indicating medium to large land holdings. Maximum farmers are literate and average family size is 7 family members per household.

Cost and return estimation of rice production

The profitability of both the methods of rice cultivation in the study area was analyzed by computing per hectare cost and returns. Cost and returns of zero tillage and conventional methods of rice production is presented in Table 1. The average operational cost per hectare was accounted to Rs. 30,876 in zero tillage method and Rs. 35,905 in conventional tillage method. The lower operational cost in zero tillage was due to lower expenses incurred mainly on human and machine labour, and irrigation than in conventional tillage method. Gross return per hectare was almost same in both the method of cultivation. However, net return accounted to Rs. 61,366 in zero tillage and Rs. 55,164 in conventional tillage. The net income was higher in zero tillage due to lower operational cost being Rs. 30,876 per hectare as compared to Rs. 35,905 in conventional tillage. The higher input-output ratio of 2.99 was observed in zero tillage as against 2.54 in conventional tillage.

Input use in rice production

The benefits in zero tillage method were mainly due to lower expenses on human labour, machine labour and irrigation which gave enough incentives to the farmers to adopt zero tillage even if output is marginally lower than conventional tillage method. As shown in Table 2, on an average farmers saved 12.95%, 41.75%, 4.64%, 10.99%

Table 1. Cost and return of rice production

Particulars	Conventional Tillage (Rs/ha)	Zero Tillage (Rs/ha)	% change
Human labour	12781	11955	-6.91
Machine labour	7632	4446	-71.66
Seeds	552	1169	52.78
Fertilizer	3507	3645	3.79
Plant protection chemicals	4863	4636	-4.90
Irrigation	3458	2648	-30.59
Overhead Cost	3112	2377	-30.92
Total Operation Cost	35905	30876	-16.29
Gross Income	91069	92242	1.27
Net Income	55164	61366	10.11
Input-Output Ratio	2.54	2.99	-

Table 2. Input use in rice production

Particulars	Conventional Tillage	Zero Tillage	% change
Human labour (man days/ha)	65.83	57.30	-12.95
Machine labour (h/ha)	12.72	07.41	-41.75
Seeds (kg/ha)	12.60	23.84	89.22
Fertilizer (kg/ha)	398.91	380.38	-04.64
Plant protection chemicals (g/ha)	2741.70	2440.36	-10.99
Irrigation (h/ha)	61.75	50.88	-17.60

Table 3. Comparison of cost and return in conventional and zero tillage methods of rice production

Particulars	Conventional tillage (Rs/ha)	Zero tillage (Rs/ha)	% change
Yield (qtl/ha)	55.70	55.08	-1.11
Operation Cost	35905	30876	-14.01
Gross Income	91069	92242	1.29
Net Income	55164	61366	11.24

and 17.60% cost per hectare on human labour, machine labour, fertilizer, plant protection chemicals and irrigation, respectively, in zero tillage than in conventional tillage of rice cultivation.

Comparative economics of rice production

The rice yield with zero tillage was slightly lower than conventional tillage. All farmers opined that weed management is a challenging task in zero tillage. A study conducted at CSSRI research farm revealed that lower yield was obtained in zero tillage as compared to the conventional tillage due to high weed manifestation (Singh et al., 2010). Therefore, the major challenge for farmers in direct seeded rice is effective weed management. Failure in weed control would result to very low yield (Moody and Mukhopadhyay, 1982; Moody, 1983). Many studies have indicated that the potential for direct seeded rice as a replacement of transplanted rice, if weeds are controlled effectively (Singh *et al.,* 2001; Singh, 2005). The gross return (Table 3) was higher in conventional tillage by 1.29%. But higher net return was obtained in zero tillage by 11.24% than conventional tillage. This was mainly due to reduction in the operational cost by 14.01% in zero tillage.

Cost and return estimation of wheat production

Cost and return estimation of zero tillage and conventional methods of cultivation of wheat are presented in Table 4. Gross return in zero tillage and conventional tillage were Rs. 68,504 and Rs. 65,036 per hectare, respectively. Similarly, net return accounted to Rs. 41,695 in zero tillage and Rs. 33,431 per hectare in conventional tillage. The net income was higher in zero tillage due to lower expenses incurred on operational cost. The average total operational cost per hectare amounted to Rs. 26,809 in zero tillage method and Rs. 31,605 in conventional tillage method of cultivation. The lower operational cost was due to lower expenses incurred on human labour, machine and irrigation in zero tillage than conventional tillage method. The higher input-output ratio of 2.56 was observed in zero tillage and it was 2.06 in conventional tillage.

Input use in wheat production

Evidence from the field investigation suggests that zero tillage is economically attractive due to higher wheat yield and lower expenses on human labour, machine labour and irrigation. As shown in Table 5, on an average, farmers saved 13.93%, 45.88%, 6.13%, and 15.98% cost on human labour, machine labour, fertilizer, and irrigation, respectively in zero tillage than conventional tillage of wheat cultivation.

Comparative economics of wheat production

Wheat yield in zero tillage was higher than conventional tillage by 5.54% (Table 6). Findings showed that among the integrated resource management technologies, zero tillage for wheat production was most successful in terms of good crop establishment and increased yield (Ladha *et al.,* 2009). The gross and net returns in zero tillage were higher by 5.33% and 24.72%, respectively. The higher net return was obtained in zero tillage mainly due to reduction in the operational cost by 15.17%. Similar results were also reported by Erenstein (2007) in his study on zero tillage.

Farmer's perception about zero tillage

Farmers who have adopted zero tillage in wheat are very much interested to continue this method of cultivation in future. According to farmer's opinion regarding zero tillage technology, germination is good and

Table 4. Cost and return estimation of wheat production

Particulars	Conventional tillage(Rs/ha)	Zero tillage(Rs/ha)	% change
Human labour	12181	10589	-15.03
Machine labour	6299	3409	-84.78
Seeds	2149	2384	9.86
Fertilizer	3389	3417	0.82
Plant protection chemicals	3520	3705	4.99
Irrigation	1388	1307	-6.20
Overhead Cost	2680	2000	-34.00
Total Operation Cost	31605	26809	-17.89
Gross Income	65036	68504	5.06
Net Income	33431	41695	19.82
Input-Output Ratio	2.06	2.56	-

Table 5. Input use in wheat production

Particulars	Conventional tillage	Zero tillage	% change
Human labour (man days/ha)	59.40	51.13	-13.93
Machine labour (hrs/ha)	10.50	05.68	-45.88
Seeds (kg/ha)	107.45	119.18	10.92
Fertilizer (kg/ha)	382.85	359.39	-06.13
Plant protection chemicals (gm/ha)	2198.30	2383.55	08.43
Irrigation (hrs/ha)	30.13	25.32	-15.98

Table 6. Comparative economics of conventional and zero tillage methods of wheat production

Particulars	Conventional tillage(Rs./ha)	Zero tillage(Rs./ha)	% change
Yield (qt./ha)	53.48	56.44	05.54
Operation Cost	31605	26809	-15.17
Gross Income	65036	68504	05.33
Net Income	33431	41695	24.72

yield is higher than conventional tillage in wheat. Sowing of crop could be done 10-15 days earlier than conventional tillage. It saves time and diesel cost during field preparation. They also opined that due to high demand and comparatively less availability of zero-till-drill in the village, many farmers remain deprived of wheat sowing by this technique.

Farmers adopted zero tillage in rice due to high labour requirement for cultivation through conventional tillage method. During transplanting and weeding farmers faced the dearth of labour availability. The conventional tillage method was a labour intensive method of rice cultivation. Although they get slightly lower yield compared to zero tillage, farmers in the study area are interested in shifting from conventional method of transplanting rice to direct seeded rice due to rising fuel prices and shortage of labour and availability of irrigation water. About 90 percent farmers expressed the view that high weed infestation with zero tillage in rice is a major limitation to adopt this technology as risk of yield loss is high. The other constraints expressed by the farmers were lesser availability and high cost of seed drill.

Conclusions

Conventional tillage method of crop establishment in rice and wheat requires a large amount of inputs. In the present scenario of rising inputs cost and labour shortage in agriculture, farmers need input saving alternative technologies to sustain crop production. The results of the present study have shown that zero tillage technology has potential to increase farmer's income and save inputs cost in both rice and wheat crops. The study revealed that the net return was higher in zero tillage mainly due to reduction in operational cost by 14.01% than conventional method of rice cultivation. In case of wheat, both yield and net returns were significantly higher in zero tillage by 5.54% and 24.72%, respectively. The saving of human labour, machine labour and irrigation were 12.95%, 41.75% and 17.60%, respectively in rice production by zero tillage method. Similarly, use of human labour, machine labour and irrigation were saved by 13.93%, 45.88% and 15.98%, respectively in zero tillage than conventional method of wheat production. Hence, zero tillage technology in rice and wheat production system promises to be an important alternative for higher farm income and saving of scarce resources in resource starved regions.

References

Bhushan, L., Ladha, J. K., Gupta, R. K., Singh, S., Padre-Tirol A., Sarawat, Y. S., Gathala, M., Pathak, H. 2007. Saving of water and labour in rice–wheat system with no tillage and direct seeding technologies. *Agronomy Journal* **99**: 1288-1296.

Erenstein, O., Malik, R. K. and Singh, S. 2007. Adoption and impacts of zero tillage in the rice-wheat zone of irrigated Haryana, India. New Delhi: CIMMYT and the Rice-Wheat Consortium for the Indo-Gangetic Plains.

Erenstein, O.2009. Adoption and impact of conservation agriculture-based resource conserving technologies in South Asia, In: Innovations for improving efficiency, equity and environment, 4th world congress on conservation agriculture, 4-7th Feb., 2009. New Delhi.

Gupta, R. K. and Seth, A. 2007. A review of resource conserving technologies for sustainable management of the rice wheat systems of the Indo-Gangetic plains. *Crop Protection* **26**: 436-447.

Ladha, J.K., Kumar. V., Alam, M. M., Sharma, S., Gathala, P., Chandna, M. K., Saharawat, Y.S., and V. Balasubramanian. 2009. Integrating crop and resource management technologies for enhanced productivity, profitability, and sustainability of the rice–wheat system in South Asia. p. 69-108. In. Ladha J K, Yadvinder Singh, Erenstein O, Hardy B, editors. 2009. Integraed crop and resource management in the rice –wheat system of south asia. Los Banos (Philippines): International rice research institute, 395p.

Malik, R.K., Yadav, A., Singh, S., Malik, R.S., Balyan, R.S., Banga, R.S, Sardana, P.K., Jaipal, S., Hobbs, P.R., Gill, G., Singh, S., Gupta, R.K., Bellinder, R. 2002. Herbicide resistant management and evolution of zero tillage–a success story. *Research Bulletin*, CCS. Haryana Agricultura University, Hisar, India. 43p.

Malik, R.K., Yadav, A., Singh, S., Sardana, P.K., Gill, G., Hobbs, P.R., Bellinder, R. 2003. Herbicide resistance management and introduction of zero tillage in wheat in India. Proc. *Weed Sci. Soc. Am.*43:55.

Moody, K., Mukhopadhyay, K. 1982. Weed control in dry seeded rice: problems, present status, research direction. In: Rice research strategy for future. Manila (Philippines): International Rice Research Institute. P 147-158.

Moody, K. 1983. The status of weed control in Asia. FAO Plant Protection Bulletin **30**: 119-120.

Singh, G. 2005. Integrated weed management in direct seeded rice. In: Singh Y, Singh G, Singh V P, Singh P, Hardy B, Johnson D E, Mortimer M, editors. Direct seeding of rice and weed management in the irrigated rice wheat cropping system of the Indo-Gangetic Plains. Pantnagar (India). Directorate of Experiment Station, G. B. Pant University of Agriculture and Technology. p 15.

Singh, R., Singh, G., Sharma, S. K., Joshi, P.K., Dey, P. and Choudhari, S.K. 2010. Evaluation of resource conservation technologies in rice-wheat cropping system Annual report. 2010-11, CSSRI, Karnal.

Singh, Y., Singh, G., Singh, V. P., Singh, R.K., Srivatsava, R.S.L., Singh, P., Mortmer, M., White, J.L. and Johnson, D.E. 2001. Direct seeding of rice in the rice wheat system of Indo-Gangetic palins and the implications for weed management. Proceedings of the International Conference. The BCPC conference: Weeds, 12-15 November 2001. Brighton, UK. 2: 187-192.

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Effect of alkali water irrigation on the production potential of potato, sunflower and sesbania

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ABSTRACT

Soil degradation due to the use of alkali waters constitutes a major threat to the irrigated agriculture, especially for the cultivation of sodicity sensitive crops. The response of potato (*Solanum tuberosum*), sunflower (*Helianthus annus*) and Sesbania (*Sesbania sesban*) green manure to the combined use of good quality canal water (CW,ECcw 1.1 dS/m, RSC nil, SAR 1.8) and alkali water (AW, ECaw 3.6 dS/m, RSC 15.8 me/L, SAR 12.4) was evaluated for 3 years (2003-2006) on a well drained sandy loam soil (ECe 2.5 dS/m, pH 7.9, exchangeable sodium percentage, ESP 5.3). Increase in soil pH (8.9-9.1), salinity (4.7-5.1 dS/m) and sodicity (ESP 25-41) as a consequence of irrigation with alkali water affected the growth and yields of all the crops. When averaged for 3 years, the relative yields (compared to CW) ranged between 57-83 and 57-73 % for cyclic use in potato and sunflower, respectively. However, these values ranged between 59-83 and 54-80% for blended waters. Considerable deterioration in produce quality was observed in terms of potato grade and weight loss on storage as well as the smaller seeds and lower oil content in the case of sunflower. The overall deterioration in soil properties under different modes was related to the proportions of AW applied. Computations further indicated that with a similar proportion of CW and AW, cyclic application CW during the initial stages would minimize the adverse effects of alkali water.

Key words: alkali water, canal water, conjunctive use, potato, sesbania, sunflower

Introduction

Degradation of soils with the use of alkali ground waters constitutes a major threat to irrigated agriculture in semi-arid climates (Minhas and Bajwa 2001; Qadir and Oster 2004). High incidence (30-50%) of these waters is found in semiarid regions (annual rainfall 500-700mm), which are the most intensively cultivated areas in the Indo-Gangetic plains. Irrigation with alkali waters results in a rise in soil alkalinity and sodicity thus adversely affecting the soil's physical behaviour in terms of crusting, hard-setting and low intake rates. This not only decreases the crop yields but also limits the choice of crops that can be grown on these soils (Minhas and Gupta, 1992; Ayers and Westcot 1985; Minhas 1996; Oster and jayawardene 1998). Specialized soil-crop-irrigation management practices, which help to maintain the sodicity in the root zone within permissible limits, are therefore advocated for sustained irrigation with alkali waters. In addition to the appropriate selection of crops and improvement in water management and the application of amendments is required to maintain soil structure/permeability.

Under certain situations, better quality canal water supplies may be available though in limited quantities and should be utilized efficiently. The ground and canal water can be applied either separately or blended together to achieve an acceptable quality for crops. Since germination and seedling establishment have been identified as the most sensitive stages in most crops, the use of better quality water has been advocated for pre-sowing irrigation and early stages of crop growth before switching over to saline waters when the crops can tolerate higher salinity (Minhas and Guptak 1992, 1993a, b; Naresh *et al.,* 1993; Rhoades *et al.,* 1992). However, in the case of alkali waters, where sodication occurs with depletion of Ca^{2+} due to its precipitation as calcite, strategies that would either minimize calcite precipitation or maximize the dissolution of precipitated calcite would be expected to perform better (Minhas and Bajwa, 2001). Usually aquifers are in equilibrium with inherent calcite, thus it seems that blending of ground waters of higher alkalinity and low calcium with canal waters would result in their under-saturation with respect to calcite. Consequently, in addition to dilution of soil solutions, irrigation with blended water/better quality canal waters should have a tendency to pick up calcium through dissolution of native calcite. Earlier reports (Bajwa and Josan, 1989a; Minhas *et al.,* 2007) indicate that cyclic use of the two waters decreased sodication of soils and thus helped in sustaining paddy-wheat yields. However, resultant benefits in terms of a decrease in calcite precipitation or its increased dissolution (and thereby sodication) are yet to be quantified under the conditions where better quality canal and alkali waters are combined and moderately sensitive crops are grown. Hence, the options of blending and cyclic use for alkali water were compared in a 3-year experiment where potato-sun-flower-Sesbania crops were grown in rotation.

Material and Methods

The experiment was conducted at the experimental farm of Raja Balwant Singh College of Agriculture, Bichpuri, Agra, Uttar Pradesh ($27^0 2'$ N and $77^0 9'$ E). The climate at the site is semi-arid with average rainfall of 650mm, about 80% of which is received during July-September. The soil at the site was a well-drained (water level below 20 m) sandy loam soil with an electrical conductivity of saturation paste extract (ECe) of 2.7 dS/m, pH of the saturation paste (pHs) of 7.9, exchangeable sodium percentage (ESP) of 5.3, organic matter content of 2.9 g/kg soil and clay content of 14%. The experiment with potato, sunflower and Sesbania crops grown in rotation was initiated during 2003 with potato as the first crop and continued till the summer season of 2006. Treatments consisted of combinations of irrigation with an alkali water (AW, Ecaw 3.6 dS/m, residual sodium carbonate (RSC) 15.8 me/l, sodium adsorption ratio (SAR) 12.4) and a good quality canal water (CW,Eccw 1.1 dS/m, RSC nil, SAR 1.8) applied either alone, as blends or in cyclic (i.e. alternate) application both irrigation-wise and crop-wise. Specifically, these treatments were:

(a) Irrigations either with CW or AW alone

(1) Irrigation with good quality canal water alone (CW, for reference)

(2) Irrigation with alkali water alone (AW)

(b) Applying the two waters cyclically either irrigation wise or crop wise,

(1) Annualy irrigations with CW and AW, with CW to start with One year canal,: two year alkali.

(2) Annualy irrigations each with CW and AW and applying AW to start with Two year alkali:One year canal

(3) Annualy irrigations each with CW and AW and applying CW to start with Two year Canal:One year alkali

(4) Annualy irrigations each with CW and AW and applying AW to start with One year alkali:Two year canal

(5) Crop-wise alternations of CW and AW, with application of AW to potato and CW to sunflower (AWp:CWs)

(c) Irrigation with blends of CW and AW

(1) Blending in the ratio of 2:1 (2CW:1AW)

(2) Blending in the ratio of 1:2 (1 CW:2AW).

Treatments were imposed in a randomized block design with four replications. The plot size was 20 m^2 (5 m x 4 m) and to control lateral fluxes of salt and water, each plot was lined with polyethylene sheet down to a depth of 0.9 m. Alkali water was synthesized by dissolving the required quantities of sodium bicarbonate in canal water. Local agronomic practices in terms of inter/intra-row spacing, seed rates, fertilizers, irrigation schedules and other cultural practices were followed for each crop. Potato (cv.Kufri-3797) was planted during the end of October and harvested during the end of February or first week of March. The crop received 100, 21 and 35 kg/ha of fertilizer nitrogen (N), phosphorus (P) and potash (K), respectively. This was followed by sunflower (cv. MSFH-17) grown from the middle of March to middle of June and fertilized with 80, 16 and 18 Kg/ha of N,P and K, respectively. Sesbania for green manuring was raised during the mon-soon season (first fortnight of July to end of August) and no fertilizers or irrigation water was applied. When the Sesbania was about 55 days old, it was turned into the soil and allowed to decompose. The rainfall received during the potato, sunflower and Sesbania seasons averaged 18.1, 32.6 and 403.8 mm, respectively (Table 1).

Soil samples were also taken to a depth of 0.9 m at planting and at harvest of the crops and soil water storage (SWS) was determined thermo-gravi-meterically. The quantity of water used (WU) was calculated as difference in soil storage during the season (SWS) plus irrigation (IW) and rainfall (RW). The water use efficiency (WUE, kg/ha-cm) was then calculated as the ratio of yield (kg/ha) to WU (cm).

Results and discussion

Changes in soil properties

The salinity and sodicity (ESP) of the surface layer of soil (0-0.3 m), where rooting is most dense and the potential for clay dispersion, surface crusting and ultimately infiltration problems are registered, is most influenced by irrigation water quality. Therefore, the effects of various modes of irrigation on the properties of this agriculturally important soil layer are presented in Fig. 1. Continuous irrigation with alkali water (AW) increased salinity and sodicity of soil compared with canal water (CW). The average values of pH, ECe, SARe and ESP at the harvest of different crops during the third year ranged between 8.9-9.1, 4.5-4.8 dS/m, 12.4-19.8 and 25.7-39.1, respectively with higher values being monitored after sunflower.

Soil sodication due to irrigation with alkali waters has been reported in the north-west parts of India (Bajwa

Table 1. Rainfall (mm), US Open pan evaporation (OPE,mm), irrigation water applied (mm) to different crops

Crop	Parameters	2003-04	2004-05	2005-06	Mean
Potato	OPE	229	257	285	257
	Rainfall	25.8	10.3	NIL	18.1
	Irrigation	250	250	300	267
Sunflower	OPE	789	775	768	777
	Rainfall	20.2	16.1	61.5	32.6
	Irrigation	420	420	420	420
Sesbania	OPE	223	231	168	207
	Rainfall	262.5	367.5	581.6	403.8
	Irrigation	NIL	NIL	NIL	NIL

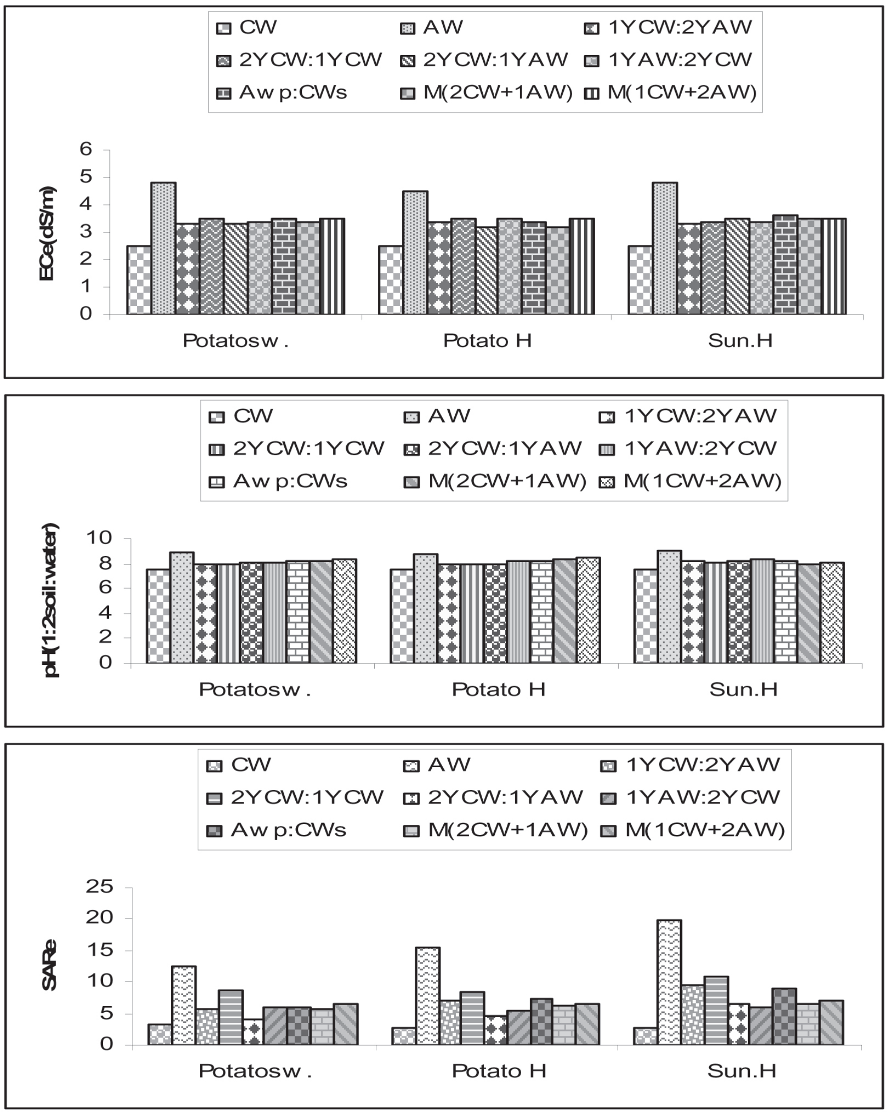

Fig.1. Effect of annually use and blending of canal (CW) and alkali(AW) waters on soil properties(0-0.3m) during the 3rd years cropping

and Josan, 1989a, b; Bajwa *et al.,* 1992, 1993; Minhas and Bajwa, 2001; Minhas *et al.,* 2007). The sodicity build up in soils irrigated with alkali waters in the north-west region has been observed to be the outcome of equilibrium between the processes of precipitation and dissolution of calcite. Precipitation occurs mainly due to concentration of the soil solution with water uptake during the cropping season while the monsoon rains induce the release of divalent cations both from exchange sites and dissolution of calcite and other minerals. In these cases, a quasiequilibrium is established within about 4-5 years of irrigation depending upon the nature of crops grown, soil characteristics and the climate especially rainfall at the site (Minhas and Gupta, 1992). Also with sodicity-induced reductions in water infiltration, the opportunity for alkali waters to penetrate deeper is reduced. The application of alkali waters further increases sodicity in the upper soil layers when concentrated through the loss of water due to evapo-transpiration. However, sodicity build up in soil (ESP –2.5 x SARaw) is greater than the earlier re-ported values of about 1.2-1.5 x SARaw for upland double crop rotations like maize/millet-wheat (Bajwa and Josan, 1989abc; Manchanda 1993; Minhas and Bajwa, 2001). This is inspite of the fact that the content of Ca^{2+} and Mg^{2+} (10.2 me/l) in alkali water used for this irrigation was much higher and the field was regularly green manured with Sesbania during the monsoon season. The latter is known to induce bioremediation in soils through dissolution of precipitated calcite in the rhizosphere because of enhanced partial pressure of carbon dioxide (pCO_2) and the production of organic acid during its decomposition (Qadir *et al.,* 2002). Moreover, with incorporation of Sesbania, the Ca and Mg taken up by the crop during its growth, was being returned to the soil. Evidences has also been generated that legumes like Sesbania rely on N_2-fixation to release protons (H^+) that contribute to a decrease in soil pH in calcareous soils and thus dissolve calcite (Qadir and Oster, 2004). These effects were evident as the ESP in surface 0.3 m soil averaged between 9 and 25 after the cessation of monsoons (harvest of Sesbania/sowing of potato) while the values ranged between 10 and 41 after the harvest of sunflower (before sowing of Sesbania), with an average decrease by 6.4 between the two monitoring periods. Nevertheless, a proportionately higher build of sodicity in the soils under the present study can be ascribed to the higher quantity of water applied (550-700 mm) and the proportion of alkali water used for irrigation of potato and sunflower when the soils were in a precipitation phase (October-June). In comparison, wheat was the main winter crop in rotation during the earlier documented studies (Bajwa and Josan, 1989abc; Manchanda 1993; Minhas and Gupta, 1992) and this crop required 350-420 mm of irrigation water. Thus, these data corroborate the recent analysis by Minhas and Sharma (2006) that in addition to the ion chemistry of irrigation waters, applied irrigation water, rainfall and evapo-transpiration of the crops also influence the extent of sodicity build up in soils irrigated with alkali waters.

The build up of salinity and sodicity in soils was also related to the proportion of AW used in various modes of irrigation while little difference was observed between respective blending and cyclic use. The pH of the surface 0.3 m soil during the third year ranged between 8.3 and 8.6 under different modes of combined use of the two waters. Similarly, the SARe varied between 4.9 and 8.8 except for the 4AW:2CW treatment where the SARe averaged 11.6 mmol/1. However, considerable differences were observed in ESP. The values averaged 12.9, 15.6, 18.6 and 21.2 for the 1Y CW:2 YAW, 2YAW:1YCW, 2CW:1YAW and 1YAW:2YCW cyclic treatments indicating an enhanced build-up of sodicity with the proportion of AW used. This was more prevalent when AW was used during the initial stages of crop growth. However, the ESP under the crop wise cyclic treatment (CWp:Aws) and different blends (2CW:1AW, 1CW:2AW) were similar (15.1-15.6). Similarly the ESP of the blended treatments were lower by 2-9. Minhas *et al.* (2006) have also reported similar results with paddy-wheat where keeping the proportion of added AW as the same; the sodicity build was similar with cyclic use and blending.

Crop performance

Irrigation with AW significantly reduced the yields of potato, sunflower and Sesbania, though the effects were comparatively smaller during the initial years(Table 2). The reductions in relative yield, RY were greater in potato (66%) and sunflower (68%) as compared with Sesbania (47%).

The reduction in crop yields can be ascribed to bicarbonate toxicity and build up of alkalinity and sodicity in soils leading to structural deterioration and poor permeability problems. These factors ultimately result in nutritional imbalances (Minhas and Gupta 1992; Qadir and Oster 2004). The restricted movement of water in soils irrigated with alkali water may also result in the retention of salts in surface layers, which simultaneously induces salinity stresses affecting crop growth (Minhas 1996; Minhas et al. 2003). The salinity (2.9-4.9 dS/m) during the crop growth period, though not high, was beyond the threshold values reported for the crops under consideration (Maas and Grattan, 1999).

The yields for each crop improved under the various combinations of CW and AW usage compared with AW alone. The crops tended to perform better with cyclic water use compared to blending. When averaged over the 3-years, the RY of potato were 73.2, 61.1, 82.2, 57.3 and 51.9% under the cyclic 1YCW:2YAW, 2YAW:1YCW, 2YCW:1YAW, 1YAW:2CW and AWp:CWs treatments, respectively while the RY was 82.9 and 59.0% for waters blended in the ratio 2CW:1AW and 1CW:2AW, respectively. Similarly, the relative yield values for sunflower were 57.8, 57.0, 72.6, 59.3 and 61.4% for cyclic uses and 79.3and 54.1% with blended waters.

Linear regressions were developed between RY's for the various fractions of AW applied under irrigation treatments of CW (nil), blend of 2CW:1AW (0.33), 1CW:2AW (0.67) and AW as such (1.0). These were then utilized to prdict RY's at the same fraction of AW for various cyclic uses. Cyclic use when canal water was used initially marginally improved yields when compared with blending. However, the yield declined slightly when 2Y

Table 2. Effect of various modes of irrigation with alkali and canal water on yield of crops during different years.

Modes of water use	Yield (Mg/ha) during the year				
	2003-04	2004-05	2005-06	Mean	RY(%)
		Potato tuber			
Canal water, CW	24.5	28.2	25.9	26.2	
Alkali water, AW	7.1	4.3	3.4	4.9	18.8
Yearly mode					
1Y CW:2YAW	23.1	17.9	16.6	19.2	73.2
2YAW:1YCW	18.8	10.8	18.4	15.9	61.1
2YCW:1YAW	19.7	24.1	20.9	21.5	82.2
1YAW:2YCW	9.3	16.8	18.9	15.0	57.3
AWp:CWs	11.4	13.5	15.9	13.6	51.9
		Blending			
2CW:1AW	21.0	22.4	31.7	31.7	82.9
1CW:2AW	13.8	15.3	17.2	15.5	59.0
LSD(p=0.05)	1.84	2.06	1.65	-	-
		Sunflower(seed)			
Canal water,CW	1.29	1.54	1.23	1.35	
Alkali water,AW	0.33	0.17	0.11	0.20	14.8
		Yearly mode			
1Y CW:2YAW	1.20	0.65	0.50	0.78	57.8
2YAW:1YCW	0.77	0.71	0.83	0.77	57.0
2YCW:1YAW	0.98	1.37	0.61	0.98	72.6
1YAW:2YCW	0.45	0.96	0.99	0.80	59.3
AWp:CWs	0.82	0.95	0.71	0.83	61.4
		Blending			
2CW:1AW	1.03	1.32	0.86	1.07	79.3
1CW:2AW	0.81	0.74	0.65	0.73	54.1
LSD(p=0.05)	0.19	0.23	0.22	-	-
		Sesbania (green matter)			
Canal water,CW	20.1	19.1	19.6	19.7	
Alkali water,AW	7.2	6.8	6.7	6.9	35.0
		Yearly mode			
1Y CW:2YAW	19.7	17.9	16.7	18.1	91.8
2YAW:1YCW	18.7	17.0	17.2	17.6	89.3
2YCW:1YAW	17.0	16.8	16.9	16.9	85.8
1YAW:2YCW	12.1	13.0	17.9	14.3	72.6
AWp:CWs	18.2	14.7	17.9	16.9	85.8
		Blending			
2CW:1AW	18.9	17.4	17.6	17.9	90.9
1CW:2AW	17.9	16.8	16.4	17.0	86.3
LSD(p=0.05)	1.0	0.7	0.7	-	-

AW irrigations were applied initially. This is consistent with earlier studies (Minhas and Gupta, 1992, 1993a, b) which show that for similar salt input, cyclic applications have an advantage over blending the water supplies especially when the better quality water is used initially at crop establishment. Similarly, Rhoades (1999) proposed that blending the low and high salinity waters can result in the loss of consumable water and more crop production can be achieved from the same total water supply if the two components are used sequentially. Thus, the results of the present study further corroborate that the same also holds for the combined use of alkali and good quality waters when the good quality water is applied initially.

Quality of produce

For potato and sunflower, soil sodicity build up under different treatments, in addition to affecting crop yields, is also reflected in terms of the quality of the produce(Fig.

Table 3. Effect of various treatments on water use efficiency in potato and sunflower and quality parameters of sunflower

Mode of water use	WUE(kg/ha-cm)		Oil content	1,000-seed
	Potato	Sunflower	(%)	weight(g)
Canal water,CW	1017	28.5	42.1	26.4
Alkali water,AW	203	4.6	37.3	16.8
		Yearly mode		
1Y CW:2YAW	760	17.0	39.9	22.2
2YAW:1YCW	632	16.5	39.6	21.8
2YCW:1YAW	872	21.1	39.9	24.3
1YAW:2YCW	623	17.1	38.9	25.1
AWp:CWs	539	17.8	39.6	22.2
		Blending		
2CW:1AW	885	22.9	40.7	26.2
1CW:2AW	625	15.8	39.8	23.8

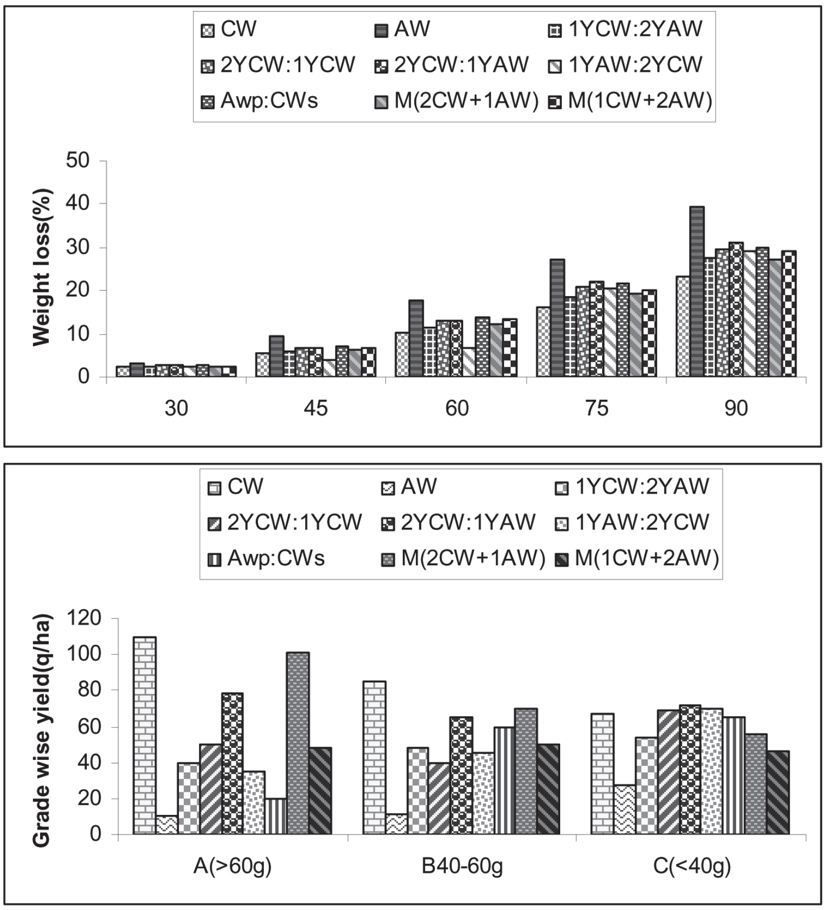

Fig. 2. Effect of various treatments on the tuber quality monitored in terms of different grades of tubers and weight loss on storage

2, Table 3). In general, the lower grade potatoes (C grade), increased with decline in yield under different treatments and the fraction of such potatoes was the greatest (0.56) when irrigated with AW compared with 0.13 for the CW treatment. Storage quality also deteriorated with AW irrigation (e.g. the potatoes shriveled with two-third-weight loss on storage for 90 days under AW treatments where as the weight loss was just about two-fifth under CW). Similarly, the quality of sunflower produce was also poor with AW producing smaller seeds (lower 1,000-seed weight) and lower oil content. The water use efficiency (WUE) also declined with reduced yields and sodicity development under various treatments (Table 3). For potatoes, WUE declined from 1017 kg/ha-cm with CW to 203 kg/ha-cm with AW, while it declined from 328.5 to 4.6 kg/ha-cm for sunflower. The values ranged between 872 and 885 kg/ha-cm for potato and 17.8-17.0 kg/ha-cm for sunflower with various CW and AW combinations.

Conclusions

It can be concluded that the combined use of alkali and good quality canal waters can maintain the soil sodium saturation at relatively low levels depending upon the proportion of the two waters. Amongst the various treatment options, the cyclic use should be preferred especially when canal waters are utilized for initial irrigations since it would have both operational and performance advantages over the blending of the water supplies. The use of AW should be avoided during the initial stages of crop growth.

References

Ayers, R.S. and Westcot, D.W. 1985. Water quality for agriculture, Irrigation and Drainage Paper No.29, Rev.1, FAO, Rome,p 174.

Bajwa, M.S. and Josan, A.S. 1989a. Prediction of sustained sodic irrigation effects on soil sodium saturation and crop yields. *Agriculture Water Management* **16**:227-228.

Bajwa, M.S. and Josan, A.S. 1989b. Effect of gypsum and sodic water irrigation on soil and crop yields in a rice-wheat rotation. *Agriculture Water Management* **16**:53-61.

Bajwa, M.S. and Josan, A.S. 1989c. Effect of alternating sodic and non-sodic irrigation on build up of sodium in soil and crop yield in northern India. *Experimental Agriculture* **25:**199-205.

Bajwa, M.S., Choudhary, O.P. and Josan, A.S. 1992. Effect of continuous irrigation with sodic and saline sodic water on soil properties and crop yields under cotton-wheat rotation in northern India. *Agriculture Water Management* **22:**345-350.

Bajwa, M.S., Josan, A.S. and Chaudhary, O.P. 1993. Effect of frequency of sodic and saline-sodic irrigation and gypsum on the build up of sodium in soil and crop yields. *Irrigation Science* **13**:21-26.

Maas, E.V. and Grattan, S.R. 1999. Crop yields as affected by salinity. In : Skaggs RW, vanShilfgaarde J (eds) Agricultural drainage. Agron. Monog. 38, ASA, CSSA, SSSA, Madison, pp-55-108.

Manchanda, H.R. 1993. Long-term use of sodic waters in North India and the reliability of equations for predicting their sodium hazard. In : Lieth H, Masoom AI A (eds) Towards the rational use of high salinity tolerant plants, Vol 2. Kluwer, The Nethrlands, pp 433-438.

Minhas, P.S. 1996. Saline water management for irrigation in India. *Agriculture Water Management* **30**: 1-24.

Minhas, P.S. and Sharma, D.R. 2006. Predictability of existing indices and an alternative coefficient for estimating sodicity build-up using adj. $R_{Na.}$ and permissible limits for crops grown on soils irrigated with waters having residual alkalinity. *Journal of Indian Society of Soil Science* **54**:331-338.

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

Minhas, P.S. and Gupta, R.K. 1993a. Conjunctive use of saline and non-saline waters I. Response of wheat to initially variable salinity profiles and modes of salinisation. *Agriculture Water Management* **23** : 125-137.

Minhas, P.S. and Gupta, R.K. 1993b. Conjunctive use of saline and non-saline waters. III. Validation and applications of a transient state model for wheat. *Agriculture Water Management* **23**:149-160.

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

Minhas, P.S., Dubey, S.K. and Sharma, D.R. 2007. Comparative effects of intera/inter-seasonal cyclic uses and blending of alkali and good quality water on soil properties and crop yields under paddy-wheat system. *Agriculture Water Management* **87 (1)**: 83-90.

Minhas, P.S., Sharma, D.R. and Chauhan, C.P.S. 2003. Management of saline and alkali waters for irrigation. In : advances in sodic land reclamation. International conference on management of sodic lands for sustainable agriculture, February 9-14, UPCAR, Lucknow, pp 122-162.

Minhas, P.S. and Gupta, R.K. 1992. Quality of irrigation water-assessment and management, ICAR Pub., New Delhi, pp 123.

Naresh, R.K., Minhas, P.S., Goyal, A.K., Chauhan, C.P.S. and Gupta R.K. 1993. Conjunctive use of saline and non-saline waters. II. Field comparisons of mixing and cyclic use modes for winter wheat. *Agriculture Water Management* **23**:139-148.

Oster, J.D. and Jayawardene, N.S. 1998. Agricultural management of sodic soils, Chap 8. In : Summer ME, Nadu R (eds) Sodic soils: distribution, processes, management and environmental consequences. Oxford University Press, UK, pp 125-147.

Qadir, M. and Oster, J.D. 2004. Crop and irrigation management strategies for saline sodic soils and waters aimed at environmentally sustainable agriculture. Science Total Environment **323**:1-19.

Qadir, M., Gafoor, A. and Martaza, G. 2002. Use of saline-sodic waters through phytoremediation of calcareous sodic soils. *Agriculture Water Management* **11**:501-521.

Rhoades, J.D. 1999. Use of saline waters for irrigation. In : Skaggs RW, van Shilfgaarde J (eds) Agricultural drainage. ASA, CSSA and SSSA, Wisconsin, pp 615-657.

Rhoades, J.D., Kandiah, A. and Mashali, A.M. 1992. The use of saline water for crop production. Irrig. & Drainage Paper No. 48. FAO, Rome, 133p.

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Effect of applied nitrogen and zinc on mustard (*Brassica juncea* L.) under sodic soil environment

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ABSTRACT

A field experiment was conducted during *rabi* season of 2008-09 at Salinity Research Farm Barwaha, Distt. Khargone M.P. to investigate the effect of applied nitrogen and zinc on mustard under sodic soil environment with the treatments comprised of four levels of N (0, 60, 80 and 100 kg/ha) and Zn (0, 2.5, 5.0 and 7.5 kg/ha) were tried in rendomized block design with three replications. The soil was fine smectitic hyperthermic family of Typic Heplusterts-sodic phase had pHs 8.7, ECe 0.79 dS/m, ESP 31.2, O.C. 0.36 %, Available nitrogen 167, phosphorus 12.0 & potassium 431 kg / ha and DTPA extractable zinc 0.46 mg/ kg. The results indicated that application of 100 kg N/ha improved dry matter yield significantely at 30, 45 and 60 days growth stages and seed & stover yield of mustard at harvest. Nitrogen @ 100 kg and zinc @ 7.5 kg per hectare increased the seed yield by 45.4 and 11.7 % ,respectively over control. The highest values of the growth characters viz. - plant height, branches per plant, siliquae per plant, seed per siliqua, and test weight were noticed at 100 kg N ha^{-1} and 7.5 kg Zn / ha^{1}. Uptake of N and Zn increased significantely up to the application of 100 kg N and 7.5 kg Zn per hectare over control. The addition of zinc improved the oil content in mustard. Application of N and Zn did not affect pHs, ECe and ESP of post harvest soil. The available N and DTPA extractable Zn increased significately with100 kg N per hectare, however, the addition of 7.5 kg Zn per hectare improved the available N and DTPA extractable Zn status of post harvest soil.

Key words: mustard, nitrogen, sodic soil, Vertisols, zinc

Introduction

Sodicity/ salinity is one of the major environmental stresses that limits growth and development of plants. Many problems are encountered in the management of such soils. Presence of high amounts of exchangeable sodium in sodic soils is main factor that inhibits crop production. Sodic soils are generally deficient in available nutrients. High exchangeable sodium interferes with plant nutrition and strongly modifies the physical condition of soil due to dispersive effect and adversely affect tranformation and availability of several elements. Almost all the crops grown in alkali soils respond to the application of nutrients. Mustard is one of the major *rabi* oilseed crop. Tiwari *et al*.(2004) reported that average productivity of this crop in Madhya Pradesh is quite low i.e. 9.68 q/ha as compared to its yield potential (25.00 q/ ha). Application of N plays a major role in improving growth and yield of mastard (Narang and Gill,1991). Zinc has specific role in growth and development and quality of oilseed crops. It is also important and helps in utilization of nitrogen and phosphorus. The information regarding N and Zn fertilization of mustard grown in sodic soil environment is very scanty, therefore, this investigation was undertaken to study the effect of N and Zn on growth, yield and nutrient uptake by mustard in sodic soil environment.

Material and methods

A field experiment was conducted during *rabi* season of 2008-09 at Salinity Research Station Barwaha, district, Khargone, Madhya Pradesh. The experimental soil (Typic Haplusterts- Sodic phase) had the following characteristics texture-clayey, pHs 8.75, ECe 0.79 dSm^{-1}, organic carbon 0.36 %, available N 167 kg/ha, available P 12 kg/ha, available K 431 kg/ha, DTPA extractable Zn 0.46 mg/ kg, CEC 38.0 $cmol_{(P+)}$/kg and exchangeable sodium percent (ESP) 31.2. The treatments comprised of four levels of N (0, 60, 80 & 100 kg/ha) and four levels of Zn (0, 2.5, 5.0 & 7.5 kg/ha) were tried in randomized block design with three replications. The mustard was sown at 30 cm apart in rows. Nitrogen and zinc were given as treatments through urea and zinc sulphate respectively. All the plots received a uniform basal dressing of P and K through single super phosphate and muriat of potash, respectively. Half of the N was given as basal and remaining half of the N was given at 30 and 45 days after sowing. Light and frequent irrigation was given as and when required to crop. Plant protection measures were adapted as per the package of practices of mustard crop. Plant samples were collected at 30, 45, 60 and at harvest from all the treatments. The plant materials were sequentially washed with distilled, 0.01 *N* HCl and then double distilled water. Plant samples and seed & stover samples were oven dried at 60°C. Nitrogen was determined in plant samples by micro Kjeldahl method as outlined by Tandon (2001). In wet digested solution P, K and Zn were determined by vanado-molybdo phosphoric acid yellow colour method (Chapman and Pratt,1961), flame photometer and atomic absorption spectrophotometer methods, respectively. Soil samples were collected at harvest of crop from all the treatments. They were air dried, crushed with wooden mortle & pestal and passed through 2 mm plastic sieve. Exchangeable sodium was estimated by the method of Richards (1954) and ESP was calculated. Available N was estimated by following standard procedures. DTPA extractable Zn was determined by atomic absorption spectrophotometer (Lindsay and Norvell, 1978).

Results and discussion

Growth and yield attributing characters of mustard

The plant height, branches per plant, silquae per plant and seed per siliqua varied with different levels of N and Zn. Addition of increasing levels of N increased the plant height, branches per plant, silquae per plant and seeds per siliqua by 18.2, 65.7, 39.0 and 24.3 %, respectively over control (Table 1). The results are in agreement with Singh and Kumar (1996) who reported that the application of 90 kg N per hectare increased the plant height, branches per plant, silquae per plant and seeds per siliqua in mustard. The increase in plant height, branches per plant, silquae per plant and seeds per siliqua was 8.9., 22.7, 8.2, 14.4 and 7.1 %, respectively due to the application of 7.5 kg Zn per hectare, over control. Enhancement in growth characters of mustard might be due to the application of Zn as reported by Gauri Shankar *et al.* (2002).

Dry matter, seed and stover yield and test weight of mustard

Application of different levels of N and Zn significantly increased dry matter of mustard at different growth stages (Table 2) and seed and stover yield. Addition of nitrogen @ 100 kg/ha gave highest dry matter at different growth stages and seed & stover yield as well as test weight of mustard. The results are conformity with those of Singh and Kumar (1996). The application of zinc @ 7.5 kg/ha improved dry matter production the tune of 30.0, 14.5 and 9.5 % at 30, 45 and 60 days growth, respectively and 11.8 and 6.4 % in seed and stover yield , respectively over control. The increment in seed and stover yield due to the application of zinc may be due to the utilization of N and P for seed through increased metabolic activities. Similar results were reported by Sakal *et al.* (1988). Nitrogen application decreased the oil content in mustard while addition of zinc increased oil content in mustard seed significantly. The increment in oil content with zinc application might be probably due to the participation of zinc as essential constituents of volatile compounds and many enzymes (Gauri Shankar *et al.*, 2002). The interaction effect of N and Zn levels was significant on the test weight of seed and stover yield and maximum value was obtained under combination of N (100 kg/ha) and Zn (7.5 kg/ha). The findings are corroborated the results of Singh and Singh (2005).

Uptake of Nitrogen and Zinc

It was observed that the application of different levels of N and Zn significantly increased N and Zn uptake at different growth stages and by seed & stover (Table 3). The highest N uptake by mustard was exhibited 85.6, 241.6 and 367.0 mg/plant at 30,45 and 60 dry growth respectively and 35.0 & 36.3 kg/ha by seed and stover, respectively at harvest due to the 100 kg N per hectare

Table 1. Growth and yield attributing characters of mustard at harvest as affected by N and Zn levels

Levels of N/ Zn (kg ha^{-1})	Plant height (cm)	Number of Branches per plant	Siliquae per plant	Seed per siliqua
N_0	119.0	3.5	44.1	8.0
N_{60}	134.0	4.9	56.5	9.3
N_{80}	137.1	5.4	58.7	10.2
N_{100}	140.7	5.8	61.8	10.8
CD 5 %	3.6	0.3	3.0	0.3
Zn_0	127.3	4.4	50.4	9.0
$Zn_{2.5}$	130.8	4.7	53.9	9.3
$Zn_{5.0}$	134.8	5.1	56.9	9.7
$Zn_{7.5}$	138.7	5.4	59.9	10.3
CD 5 %	3.6	0.3	3.0	0.3

Table 2. Drymatter yield, test weight and seed & stover yield of mustard as affected by N and Zn levels

Levels of N/ Zn(kg ha^{-1})	Dry matter yield (g/plant) 30 DAS	45 DAS	60 DAS	1000 Seed wt. (g)	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Oil Content (%)
N_0	1.14	4.30	9.80	3.40	938	2215	37.4
N_{60}	1.39	6.37	11.9	4.41	1130	2606	36.3
N_{80}	1.86	6.98	13.1	4.51	1284	2731	35.4
N_{100}	2.34	7.62	13.8	4.57	1364	2832	34.5
CD 5 %	0.06	0.26	0.16	0.08	26	20	0.9
Zn_0	1.43	5.85	11.60	3.40	1111	2513	34.9
$Zn_{2.5}$	1.65	6.20	12.00	3.63	1154	2573	35.5
$Zn_{5.0}$	1.79	6.51	12.40	3.80	1209	2622	36.1
$Zn_{7.5}$	1.86	6.70	12.70	4.10	1242	2675	37.0
CD 5 %	0.06	0.26	0.16	0.08	26	20	0.9

Levels of N (Kg ha^{-1})	Levels of Zn (kg ha^{-1}) Zn_0	$Zn_{2.5}$	$Zn_{5.0}$	$Zn_{7.5}$	Mean
			1000 seed weight (g)		
N_0	3.40	3.63	3.80	4.10	3.40
N_{60}	4.41	4.43	4.44	4.45	4.41
N_{80}	4.50	4.52	4.53	4.56	4.50
N_{100}	4.57	4.57	4.60	4.69	4.57
Mean	3.40	3.63	3.80	4.10	
	N	Zn	NxZn		
CD at 5%	0.08	0.08	0.16		
			Stover yield (kg/ha)		
N_0	2184	2203	2220	2553	2215
N_{60}	2497	2566	2640	2719	2606
N_{80}	2635	2719	2764	2806	2731
N_{100}	2737	2804	2866	2920	2832
Mean	2513	2573	2622	2675	
	N	Zn	NxZn		
CD at 5%	20	20	39		

Table 3. Uptake of N and Zn by mustard at different growth stages as affected by N and Zn levels

Stage	Unit	Levels of Nitrogen N_0	N_{60}	N_{80}	N_{100}	CD 5%	Levels of Zinc Zn_0	$Zn_{2.5}$	$Zn_{5.0}$	$Zn_{7.5}$	CD 5%
						Nitrogen					
30 DAS	mg/plant	31.6	46.3	65.8	85.6	2.4	46.8	55.6	61.5	65.4	2.4
45 DAS	mg/plant	85.4	169.1	200.2	241.6	11.3	150.3	169.9	181.1	194.9	11.3
60 DAS	mg/plant	168.2	248.6	299.8	367.0	12.6	239.3	259.7	283.7	301.0	12.6
Seed	kg/ha	20.0	26.9	31.6	35.0	0.8	25.9	27.4	29.6	30.6	0.8
Stover	kg/ha	14.9	26.3	31.8	36.3	2.1	25.0	26.7	27.9	29.9	2.1
						Zinc					
30 DAS	mg/plant	0.042	0.063	0.090	0.119	0.004	0.050	0.075	0.089	0.100	0.004
45 DAS	mg/plant	0.117	0.201	0.236	0.277	0.015	0.124	0.180	0.243	0.283	0.015
60 DAS	mg/plant	0.183	0.271	0.333	0.387	0.028	0.188	0.249	0.329	0.411	0.028
Seed	kg/ha	0.151	0.200	0.254	0.300	0.045	0.122	0.206	0.261	0.316	0.045
Stover	kg/ha	0.269	0.456	0.571	0.697	0.069	0.280	0.454	0.565	0.694	0.069

Table 4. Effect of different levels of N and Zn on available nitrogen, DTPA extractable zinc and ESP of soil at harvest

Levels of N/ Zn(kg ha^{-1})	Available N (kg/ha)	DTPA extractable Zn (mg/kg)	ESP
N_0	140	0.65	30.4
N_{60}	162	0.70	30.2
N_{80}	171	0.75	29.6
N_{100}	176	0.78	28.9
CD 5 %	4.0	0.03	NS
Zn_0	156	0.62	30.5
$Zn_{2.5}$	160	0.69	30.2
$Zn_{5.0}$	165	0.76	29.4
$Zn_{7.5}$	169	0.82	28.9
CD 5 %	4.0	0.03	NS

application might be due to greater absorption of N and higher dry matter/seed and stover yields. This confirms the findings of Sharma and Kumar (1990). The maximum N uptake by mustard was 65.4, 194.9, 301.0 mg/plant at 30, 45 and 60 days growth respectively and 30.6 and 29.9 kg/ha by seed and stover at harvest respectively by the application 7.5 kg Zn per hectare. Similar results were also reported by Jat and Mehra (2007). The highest uptake of Zn was 0.119, 0.277 and 0.387 mg/plant at 30, 45 and 60 days growth and 0.300 and 0.697 kg/ha by seed and stover respectively with the application of 100 kg N per hectare (Table 3). The results are in conformity with those reported by Nayak *et al*. (1997). The maximum Zn uptake by mustard was 0.100, 0.283 and 0.411 mg/plant at 30, 45 and 60 days growth and 0.316 & 0.694 kg ha^{-1} by seed and stover, respectively with 7.5 kg Zn per hectare. Similar findings were also reported by Krishna and Singh (1992).

Available nitrogen, DTPA extractable zinc and ESP of the soil after harvest

Application of different levels of N and Zn significantly increased the available N, and DTPA extractable Zn contents in post harvest soil. Addition of 100 kg N per hectare ehhanced the available N and DTPA extractable Zn by 25.7 and 20.0 % over control respectively. This corroborates with the findings of Duraisami *et al.* (2001) Aulakh and Malhi (2005).

The maximum available N and DTPA extractable Zn contents in soil was 169 and 0.82 kg/ha, respectively with 7.5 kg/ha applied Zn. The improvement in available N content of soil due to the application of Zn is because of the fact that the Zn plays a vital role in various enzymatic activities in soil and also acts as a catalyst in hormones production and protein synthesis. Similar results were reported by Deo and Khandelwal (2009). The slight decrease was observed in exchangeable ESP of the soil with addition of different levels of N and Zn. But the differences were non-significant.

References

Aulakh, M.S. and Malhi, S.S. 2005. Interactions of nitrogen with other nutrients and water: Effect on crop yield and quality, nutrient use efficiency, carbon sequestration and environmental pollution. *Advance in Agronomy* **86**: 341-344.

Chapman, H.D. and Pratt, P.F. 1961. Methods of analysis for soil, plant and water. University of California, U.S.A.

Deo, Chandra and Khandelwal, R. B. 2009. Effect of zinc and phosphorus on yield, nutrient uptake and oil content of mustard grown on the gypsum treated sodic soil. *Journal of Indian Society of Soil Science* **57**:66-70.

Duraisami, V. P., Perumal, Rani and Mani, A. K. 2001. Changes in organic carbon, available nitrogen and inorganic nitrogen fractions under integrated nitrogen management of sorghum in a mixed black soil. *Journal of Indian Society of Soil Science* **49:** 435-439.

Gouri Shankar, L.P., Singh, Room,Shankar, G. And Singh, R. 2002. Efeect of integrated nutrient management on yield and quality of Indian mustard (*Brassica juncea*) and properties of soil. *Indian Journal Agricultural Sciences* **72**: 551-552.

Jat, J. R. and Mehra, R. K. 2007. Effect of sulphur and zinc on yield, macronutrient content in and uptake by mustard on haplusterpts. *Journal of Indian Society of Soil Science* **55**: 190-195.

Krishna,S. and Singh, R.S. 1992. Effect of zinc on yield, nutrient uptake and quality of Indian mustard. *Journal of Indian Society of Soil Science* **40**: 321-325.

Lindsay, W. L. and Norvell, W. A. 1978. Development of DTPA soil test for zinc, iron, manganese and copper. *Soil Science Society of America Journal* **42**: 421-428.

Narang, R.S. and Gill, M.S. 1991. Nitrogen response,stress and use efficiency studies in Gobhi Sarson(*Brassica napus*) grown under different levels of irrigation and nitrogen. *Fertilizer News* **36** (10):37-45.

Nayak, R., Chouhan, R. P. S. and Singh, G. 1997. Effect of nitrogen and zinc on wheat *(Triticum aestivum*) yield and nutrient uptake under partially reclaimed sodic soil. *Indian Journal of Agronomy* **42**: 293-296.

Richards, L. A. 1954. Diagnosis and improvement of saline and alkali soil. Hand book no. 60 USDA, Washington, D. C.

Sakal, R., A. P.Singh, and S. P. Singh 1998. Distribution of available Zn, Cu, Fe and Mn in old alluvial soils as related to certain soil characteristics. *Journal of Indian Society of Soil Science* **36**: 59-63.

Sharma, D.K. and Kumar, A. 1990. Effect of nitrogen on yield, uptake, recovery and nitrogen use efficiency of mustard under different irrigation scheduling. *Journal of Indian Society of Soil Science* **38** : 229-232.

Singh, B. and Kumar, V. 1996. Response of Indian mustard (*Brassica juncea*) to nitrogen and sulphur application under rainfed condition. *Indian Journal of Agronomy* **41**: 286-289.

Singh, S. P. and Singh, V. 2005. Effect of nitrogen, sulphur and zinc on Indian mustard (*Brassica juncea* L.). *Indian Journal of Agricultural Sciences* **75**: 828-830.

Tandon,H.L.S. 2001. Methods ofanalysis of soils, plants,water and fertilizer. Fertilizers Development and Consultation Organization, New Delhi.

Tiwari, G., Sharma, R. S. and Dwivedi, S. K. 2004. Chlorophyll content and its composition in mustard as affected by nitrogen and sulphur under rainfed condition. *Jawaharlal Nehru Krishi Vishwavidyalaya Research Journal* **38:** 51-54.

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Potassium Release Properties from Long Term Fertilization and Manuring in Rice-Wheat System under Sodic Water Irrigation

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ABSTRACT

In a long-term fertilizer experiment, the effect of NPK fertilizers alone and in combination with gypsum, farmyard manure (FYM), sulphitation press-mud (SPM), gypsum plus FYM, and gypsum plus SPM on phosphorus (P) and potassium (K) supply and release pattern in rice-wheat cropping sequence was evaluated on Acquic Natrustalfs. In all the fertilizer and manure treatments, removal of K in the crop exceeded K additions and the total soil K balance was negative. Apparent potassium use efficiency of applied K in the 100% NPK treated plot was lower as compared to 100% NPK + GM and 100% NPK + FYM treated plots. The distribution pattern of the water soluble, exchangeable and non-exchangeable K, at various depths of soil profile indicated that a major portion of the applied K remained in the top 30 cm soil and moved in successively decreasing amounts down the profile to a depth of 60 cm in the plots receiving K fertilizer. The neutral 1 N ammonium acetate-extractable K in the surface soil (0-15 cm) ranged from 187 to 324 kg ha^{-1} in different treatments. The highest and lowest values were obtained in 150 % NPK and 100 % NP treatments, respectively. It was observed that in plots receiving fertilizer K, the contribution of non-exchangeable K to plant uptake was lower as compared to without K fertilization (control, 100 % N and 100% NP). The results suggest that sub-soil layers are also stressed for K and the continuous mining of soil reserve K may affect crop yields adversely in long-term.

Key words: alkali water, gypsum, phosphorus, potassium, press mud, rice-wheat

Introduction

In many arid and semi-arid regions of the world, sodic groundwater is the main or only source of irrigation and its use poses a threat to the agricultural production. Application of gypsum as soil or water amendment is commonly recommended to offset such deteriorating effects due to the application of sodic water. Gypsum effectiveness on soil reclamation has been extensively reported. The use of sodic waters increases pH, SAR and ESP in the soils and leaves adverse effects on crop. In most of the cropping systems practiced in India, potassium (K) balance in soil is negative. Though these soils contain adequate K before reclamation, its status goes down after continuous cropping (Swarup and Singh, 1989). Therefore, there is need to continuously assess the removal of K in these cropping sequences. It is well known that with K fertilizer use, its status in soil is either maintained at the original level or even increased (Cooke et al., 1958; Goswamy and Benerjee, 1978; Swarup and Ghosh, 1978; Swarup and Singh, 1987, 1989; Bajwa 1994; Yaduvanshi, 2002). Several studies have shown substantial contribution of non-exchangeable K (up to 80 - 95 %) towards K nutrition of crops grown on illite dominant alluvial soils (Sachdeva and Khera, 1980; Swarup and Chillar, 1986, Yaduvanshi, 2002). Comparative K release studies of differentially fertilized soils of similar mineralogical composition provide insights into the complex behavior of soil K under cultivated conditions. The K release behavior from soils under long-term cropping, fertilization and manuring also helps to predict the fate of added K. Therefore, the present study examined the effect of 10 years of rice-wheat cropping receiving fertilization/manuring on K availability and non-exchangeable K release under sodic water irrigation conditions in sodic soil.

Material and Methods

A field experiment was initiated in 1994 with kharif (wet season) rice (*Oryza sativa* L.) and rabi (winter season) wheat (*Triticum aestivum* L.) cropping system at the Bhaini Majra Experimental Farm, Kaithal under Central Soil Salinity Research Institute, Karnal, India. The experimental site is situated at latitude of 29.80^{0} N and longitude of 76.45^{0} E and is about 250 m above the mean sea level. The soil is classified as Acquic Natrustalfs according to Soil Taxonomy with illite as a dominant

Table 1. Initial soil and water analysis of experimental site

Soil properties	
pH_e	8.6
Sodium absorption ratio (SAR) (m mol/l)$^{1/2}$	29.0
Exchangeable Ca + Mg (meq/100 gm)	1.66
Organic Carbon g kg^{-1}	4.0
Available N (kg ha^{-1})	125.0
Available P (kg ha^{-1})	14.8
Available K (kg ha^{-1})	275.0
DTPA extractable Zn (kg ha^{-1})	1.99
Water properties	
pH	9.00
EC (dS m^{-1})	2.01
Residual sodium carbonate (RSC) (meq l^{-1})	8.50
Ca + Mg (meq l^{-1})	9.00
CO3 HCO3 (meq l^{-1})	17.5
Na (meq l^{-1})	18.6
SAR (m mol/l)$^{1/2}$	8.8

mineral. Initial soil properties of the field are given in Table 1. There were ten treatments consisting of: T_1: control with no inorganic fertilizer or organic manure/ amendment; T_2: 120 kg N ha^{-1} only; T_3: 120 kg N ha^{-1} + 26 kg P ha^{-1}; T_4: 120 kg N ha^{-1} + 26 kg P ha^{-1} + 42 kg K ha^{-1}; T_5: T_4 + 20 kg $ZnSO_4$ ha^{-1} before rice transplanting; T_6: T_4 + 10 Mg ha^{-1} FYM before rice transplanting; T_7: T_4 + 5 Mg ha^{-1} gypsum before rice transplanting; T_8: T_4 + 10 Mg ha^{-1} FYM + 5 Mg ha^{-1} gypsum before rice transplanting; T_9: T_4 + 10 Mg ha^{-1} press-mud before rice transplanting and T_{10}: T_4 + 10 Mg ha^{-1} press-mud + 5 Mg ha^{-1} gypsum before rice transplanting. The last two treatments with pressmud (T_9 and T_{10}) were included during 1997 rice season. The N, P and K doses were applied through urea, single super phosphate and muriate of potash respectively to both the crops. The experiment was laid out in a randomized block design with four replications. The experiment was continued in the fixed layout each year during 1994-2004. The crops were grown under irrigated conditions. At each irrigation, rice plots were flooded with 2.5 cm deep standing water. Subsequent irrigations were given when soil water reached the saturations level (*i.e.* no standing water). The analysis of irrigation water is presented in Table 1.

The farmyard manure (FYM), sulphitation press-mud (SPM) and gypsum were incorporated in the soil 15 days before transplantation of rice each year. Nutrient contents of 10 Mg ha^{-1} FYM (20 % moisture) and 10 Mg ha^{-1} SPM (40 % moisture) are given in Table 2. Seedlings of rice cv. Jaya (35 days old) were transplanted in standing water (5 $\pm$ 1 cm) in the first week of July each year at a spacing of 20 cm between rows and 15 cm between plants. One third of N and full amounts of P and K were added at the time of transplanting. The remaining amount of nitrogen was broadcast in two equal splits at 3 and 6 weeks after transplanting. The rice crop was harvested in the third week of October every year. Grain yield of rice was computed to 14% moisture content and straw yield on oven dry basis.

The residual effect of gypsum, zinc sulphate, FYM and SPM was evaluated on the succeeding wheat crop. Wheat cv. HD 2329 (1994-95 to 1999-2000) and PBW 343 (during 2001-02) was sown during second week of November at a row spacing of 20 cm at a rate of 100 kg seed/ha. The inorganic fertilizer treatments as given to rice were also applied to wheat. One third dose of N and the full amount of P and K were applied at the time of sowing. The remaining dose of nitrogen was top dressed in two equal splits at 3 and 6 weeks after sowing. The sources of N, P and K were urea, single superphosphate and muriate of potash respectively. Wheat crop was harvested during second week of April each year. Yields of both grain and straw were recorded on air-dry basis at prevailing temperature of about 40 °C in the month of April.

Soil samples were taken at 15 cm intervals up to the depth of 120 cm from 4 replicates of each treated plot after 10 cycles of rice-wheat rotation (after wheat crop in 2003-04). The soil samples were air-dried and ground to pass through a 2 mm sieve and were analyzed for water soluble (1:5 soil: water ratio), exchangeable (1N neutral ammonium acetate) and non-exchangeable (*1N* boiling HNO_3) forms of potassium (Black, 1965). The contribution of non-exchangeable K towards total K uptake by plants was calculated using the following relationship:

K uptake from non-exchangeable form = Total K uptake by plants + available K in soil after Cropping Fertilizer K added – available K in soil before cropping.

Table 2. N, P and K in farmyard manure and sulphitation pressmud and quantities added (oven dry basis)

Elements	Concentration		Quantity of nutrient added kg per ha per year	
	FYM	SPM	8 Mg ha^{-1} FYM	6 Mg ha^{-1} SPM
N (%)	0.56	1.52	44.8	91.2
P (%)	0.234	0.53	18.7	31.8
K (%)	0.868	1.20	69.4	72.0
Zn (mg kg^{-1})	71	223	0.57	1.34

Table 3. Distribution of water soluble K (mg kg^{-1}) in soil profile after 10 years of rice-wheat cropping under sodic water irrigation

Treatments	Soil depth (cm)					
	0-15	15-30	30-45	45-60	60-90	90-120
T_1 $N_0P_0K_0$	86	64	57	49	43	37
T_2 $N_{120}P_0K_0$	76	55	50	44	38	35
T_3 $N_{120}P_{26}K_0$	69	58	39	36	35	32
T_4 $N_{120}P_{26}K_{42}$	79	65	55	51	46	48
T_5 $N_{120}P_{26}K_{42}$ + Zn	71	65	50	49	45	43
T_6 $N_{120}P_{26}K_{42}$ + FYM	83	81	67	36	34	34
T_7 $N_{120}P_{26}K_{42}$ + gypsum	82	61	52	46	45	49
T_8 $N_{120}P_{26}K_{42}$+FYM + gypsum	91	76	55	48	41	37
T_9 $N_{120}P_{26}K_{42}$ + SPM	87	65	60	51	41	28
T_{10} $N_{120}P_{26}K_{42}$ + SPM + gypsum	81	61	53	49	36	32
CD at 5 %	10.70	11.25	8.28	7.57	8.52	7.83

Table 4. Distribution of 1 N NH_4OAc extractable K (kg ha^{-1}) in soil profile after 10 years of rice-wheat cropping under sodic water irrigation

Treatments	Soil depth (cm)					
	0-15	15-30	30-45	45-60	60-90	90-120
T_1 $N_0P_0K_0$	218	270	262	251	242	158
T_2 $N_{120}P_0K_0$	245	263	258	250	255	167
T_3 $N_{120}P_{26}K_0$	236	255	267	249	247	168
T_4 $N_{120}P_{26}K_{42}$	288	300	302	275	256	157
T_5 $N_{120}P_{26}K_{42}$ + Zn	289	313	281	279	252	156
T_6 $N_{120}P_{26}K_{42}$ + FYM	312	339	328	294	267	182
T_7 $N_{120}P_{26}K_{42}$ + gypsum	308	328	324	302	263	190
T_8 $N_{120}P_{26}K_{42}$+FYM + gypsum	324	334	329	295	258	194
T_9 $N_{120}P_{26}K_{42}$ + SPM	318	333	298	268	249	188
T_{10} $N_{120}P_{26}K_{42}$ + SPM + gypsum	321	322	296	265	255	210
CD at 5 %	45.4	52.2	41.3	31.1	48.9	42.4

Results and Discussion

The distribution of water soluble and exchangeable K content of the top (0-15 cm) soil in the treatments receiving K fertilizer (150 % NPK, 100% NPK and 100 % NPK + FYM or GM) was higher as compared to 100% N or 100% NP treatments (Tables 3 and 4). Similar results were observed at 15-30, 30-45 and 45-60 cm soil depths. Lower values of K observed in the N and NP treatments were caused by mining of soil K due to removal of crops in the rotation. The higher values of K in 150 % NPK, 100% NPK and 100 % NPK + FYM or GM treated plots indicated greater release of K in soil solution. The exchangeable K status increased from its initial value of 220 kg ha^{-1} to 287 kg ha^{-1}, 299 kg ha^{-1}, 295 kg ha^{-1} and 310 kg ha^{-1} when 100% NPK, 100% NPK + GM, 100% NPK + FYM and 150 % NPK were applied (Table 4). In sub-surface soil layers, the higher release rates were obtained in the treatments having K as compared to the treatments without K fertilization thereby indicating that the soils were stressed for K in these treatments. After the harvest of 20 crops (10 rice + 10 wheat) and in spite of a substantial K uptake, the exchangeable K status was reduced marginally (21 - 33 kg ha^{-1}) from the initial value of 220 kg ha^{-1} in the treatments which did not receive K fertilizer (Table 4). The clay minerals present in these soils are predominantly illite having high K content, and hence the K release from such minerals during cropping periods might have been sufficient to meet the crops requirement. Swarup and Singh (1989) and Yaduvanshi (2002) also did not observe any significant effect of K fertilizer on grain yield of rice and wheat.

Distribution of non-exchangeable K in the soil profile (Table 5) indicated a small increase in its content in treatments receiving K fertilizers. It is also evident that K was released from non-exchangeable reserves in the surface layers of soils in all the plots. This reserve was more in plots receiving N and P fertilizers as compared with the control. Irrespective of the K treatments, K was depleted in all plots under rice-wheat cropping system, thereby indicating a state of continuous stress on the soil

Table 5. Distribution of non-extractable K (kg ha^{-1}) in soil profile after 20 cycles of rice-wheat crop under sodic water irrigation

Treatments	Soil depth (cm)					
	0-15	15-30	30-45	45-60	60-90	90-120
T_1 $N_0P_0K_0$	3937	3228	4118	3650	3458	3570
T_2 $N_{120}P_0K_0$	3863	4315	4047	3625	3361	2956
T_3 $N_{120}P_{26}K_0$	4058	3625	3788	3701	3608	3679
T_4 $N_{120}P_{26}K_{42}$	3964	4074	4333	4152	3805	3517
T_5 $N_{120}P_{26}K_{42}$ + Zn	3501	3997	3543	3641	3322	2887
T_6 $N_{120}P_{26}K_{42}$ + FYM	3797	4084	4596	4158	3380	2686
T_7 $N_{120}P_{26}K_{42}$ + gypsum	3428	3668	3198	3342	3283	2939
T_8 $N_{120}P_{26}K_{42}$ + FYM + gypsum	4096	3801	3674	3561	3324	2681
T_9 $N_{120}P_{26}K_{42}$ + SPM	4274	3740	3731	3625	3293	2727
T_{10} $N_{120}P_{26}K_{42}$ + SPM + gypsum	4150	3641	3350	3758	3516	2959
CD at 5 %	350	405	410	342	322	396

system to meet the K requirements of the crops. Even in plots given K fertilizer, the total uptake of potassium by the crops far exceeded the amount of K applied. Mean K uptake by crops in different treatments ranged from 752 kg ha^{-1} in control to 2731 kg ha^{-1} in NPK + GM (Table 6). Those plots which did not receive K fertilizer (control, N and NP) exhibited more contribution of soil K to crops (Table 6). In calculating the contribution of non–exchangeable K to total K uptake of crops losses due to leaching could not be accounted for and therefore zero leaching is assumed. Fertilizer K application considerably reduced the contribution of non-exchangeable K to total K uptake. It was observed that in plots receiving fertilizer K (100 % and 150 % NPK and 100 % NPK with FYM or GM) the contribution of non-exchangeable K to plant uptake was lower as compared to NP and N which could be an external supply of 840, 1740, 1540 and 1260 kg K ha^{-1} by 100 % NPK, 100% NPK + GM, 100 % NPK + FYM and 150 % NPK treatments, respectively. This implies that continuous cropping with high levels of N and P would result in a gradual depletion of K reserves thereby rendering the soils responsive to K in the future. With the addition of K from K fertilizer and organic manures (green manuring and FYM) during the period under study, K uptake increased over the respective zero K treatment (Fig.1 and Table 6). This, however, was not due to high dry matter yield, but may be due to luxury consumption of K following its application. The concentration of K in the grains of both crops remained unaffected but in straw it increased significantly (Data not shown) as also reported by Swarup and Ghosh (1978) and Yaduvanshi (2002). In both the crops, N application enhanced the K concentration in straw.

Apparent potassium use efficiency of applied K in the 100% NPK treated plot was about 45.6 %, which

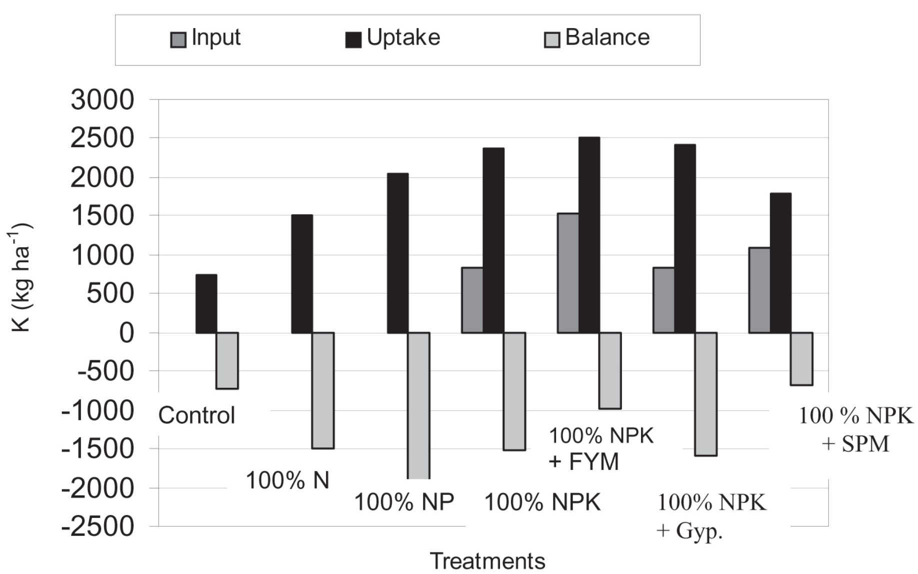

Fig. 1. Apperent K balance (K added minus K removed) for rice-wheat during 10 years of cropping

Table 6. Removal and addition of potassium (kg ha^{-1}) in ten years of rice wheat cropping sequence (1994-95 to 2003-04) under sodic water irrigation

Treatments	Fertilizer K addition (kg ha^{-1}) (Rice+Wheat)	Available K (kg ha^{-1}) after 2003-04 wheat	Total K uptake crops (kg ha^{-1})	Contribution of non-exchangeable K (kg ha^{-1})	% contribution
T_1 $N_0P_0K_0$	nil	218	738	681	92.3
T_2 $N_{120}P_0K_0$	nil	245	1508	1478	98.0
T_3 $N_{120}P_{26}K_0$	nil	236	2034	1995	98.1
T_4 $N_{120}P_{26}K_{42}$	840	288	2368	1541	65.1
T_6 $N_{120}P_{26}K_{42}$ + FYM	840 + 694[a]	312	2516	1019	40.5
T_7 $N_{120}P_{26}K_{42}$ + gypsum	840	308	2421	1614	66.7
T_8 $N_{120}P_{26}K_{42}$+FYM + gypsum	840 + 694[a]	324	2578	1093	42.4
T_9 $N_{120}P_{26}K_{42}$ + SPM	588 + 504[b]	318	1781	732	41.1
T_{10} $N_{120}P_{26}K_{42}$ + SPM + gypsum	588 + 504[b]	321	1839	793	43.1

a= K addition from FYM

b= K addition from SPM and SPM value show 7 years crop sequence

increased to 55.6 % in 100% NPK + GM and 54.4 % in 100% NPK + FYM treated plots (Table 6). This could be due to higher crop removal of soil potassium and its available content in all the treatments.

Conclusions

Long-term rice-wheat cropping system with NPK fertilizer and manuring significantly influence the availability and release of soil K. Both exchangeable and non-exchangeable K decreased in the treatments without K fertilization. The non-exchangeable pool of the soil K mainly supplied K to the crops. These soils could still be cropped without K fertilization.

References

Bajwa, M.I. 1994. Soil potassium status, potash fertilizer usage and recommendations in Pakistan. *Potash Review*, No. 3, 1994, Subject 1, Basel Switzerland, International Potash Institute

Black, C.A. 1965. *Methods of Soil Analysis*. Part II, American Society of Agronomy. Madison, Wisconsin, USA.

Cooke, G.W., Mattingley, G.E.G. and Williams, P.J.B. 1958. Changes in the soil of long continued field experiment at Saxmundhan, Suffolk, *Journal of Soil Science* **9**: 298-305

Goswami, N.N. and Benerjee, N.K. 1978. Phosphorus, potassium and other macro elements. In Soils and Rice International Rice Research Institute, Manila, Philippines. 561 pp

Sachdeva, C.B. and Khera, M.S. 1980. Utilization of K from non-exchangeable sources in soil under intensive wheat-bajra cropping system, *Fertilizer News* **25**: 6-19.

Swarup, A. and Chillar, R.K. 1986. Buildup and depletion of soil phosphorous and potassium and their uptake by rice and wheat in long-term field experiment. *Plant and Soil* **91**: 161-170.

Swarup, A. and Ghose, A.B. 1978. Effect of intensive fertilizer use based on soil tests on the available potassium status in soil and potassium content of crops, *Indian Journal Agronomy* **23**: 289- 294.

Swarup, A. and Singh, K.N. 1987. Movement of potassium in a sodic soil profile as influenced by long-term use of inorganic fertilizer under rice-wheat rotation. *Journal of the Indian Society of Soil Science* **35:** 253-256.

Swarup, A. and Singh, K.N. 1989. Effect of 12 years rice/ wheat cropping sequence and fertilizer use on soil properties and crop yields in a soil. *Field Crop Research* **21**: 277-287.

Swarup. A. and Yaduvanshi, N.P.S. 2000. Effects of integrated nutrient management on soil properties and yield of rice in alkali soils. *Journal of the Indian Society of Soil Science* **48:** 279- 282.

Yaduvanshi, N.P.S. 2002. Budgeting of P and K for a rice-wheat cropping sequence on a sodic soil. Tropical Agriculture (Trindad) **79**: 1-6.

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Moisture characteristics curves of saline and alkaline Inceptisols and Vertisols

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ABSTRACT

Water retention characteristics surface samples of twenty swell-shrink soils widely occurring in five agro-climatic zones of Maharashtra were studied. Kandegaon series retained higher water throughout the matric suction range as compared to other soils. About 45-50 per cent water was desorbed between 0 and 33 kPa suction levels through these soils. The total water was distributed in the order Drainable water > Residual water > Available water. The relationship between soil-water content and matric suction was described as $Y=aX^{-b}$. Specific water capacity values were minimum near saturation and increased with increase in matric suction. Surface area, per cent clay content and CEC were the major physical and chemical properties affecting water retention at saturation and matric suction of 33 and 1500 kPa.

Introduction

Retention, release and movement of water through soils are basically decided by the water retention characteristic curve, therefore it has direct relevance to the crop production and successful soil and water management. To ascertain the quantity of available water, knowledge of soil-water release pattern is essential. Physical and chemical properties of soil influence soil-water retention and quantum of water available to the plant species (Gupta et al.1983, Ohu et al.1987). Water retention characteristics of five pedons (three Vertisol, and one each Entisol and Inceptisol) from Dadra and Nagar Haveli area were studied by Challa and Gaikwad (1987). Biswas and Ali (1967) studied the influence of organic carbon and clay content on permanent wilting percentage of alluvial, black and lateritic soils. The information on this aspect is available for a few locations in Maharashtra. Therefore, an attempt was made to study the water retention characteristics and its predictability using easily measurable physical and chemical properties of twenty swell-shrink soils located in different agro-climatic zones of Maharashtra.

Materials and methods

Surface soil samples (0-15 cm) of 20 widely occuring swell-shrink soil series located in five agro-climatic zones of Maharashtra State were collected. Five zones included zone II (transitional zone with mean annual rainfall of 1456 mm), zoneIII (scarcity tract, arid to semi-arid with mean annual rainfall of 588 mm), zone IVA (zone of assured rainfall with kharif cropping, annual rainfall of 857 mm), zoneIVB (zone of assured rainfall with kharif and rabi cropping, annual rainfall of 730 mm) and zone VB (zone of moderately high rainfall with trap soil, annual rainfall of 1088 mm). The details of the soil samples collected are given in Table 1. Some of the important physical and chemical properties are presented in Table 2. The physical and chemical properties were determined using standard procedures described by Page et al. (1982) and Jackson (1973). All the soils were clayey in texture.

Water retention in low suction range (0-20 kPa) was determined by modified Haines method using a sintered glass funnel as described by Day et al. (1967). In this range water retention was determined at 0, 10 and 20 kPa suctions. Whereas, in high suction range (33-1500 kPa) a pressure plate apparatus was used to determine the water retention at 33,40,50,80,100,200,300,400,800 and 1500 kPa suctions as described by Bruce and Luxmoore (1986).

To study the water distribution pattern, total water was divided in three distinct ranges (Rijov 1973) called drainable water (water retained between 0 and 33 kPa), available water (water retained between 33 and 1500 kPa) and residual water (water retained at 1500 kPa). An empirical relationship of the form $Y=aX^{-b}$ was fitted to water content and matric suction data and specific water capacity at 10, 33, 80, 400, 800 and 1500 kPa was estimated as the slope of above empirical relationship at these suction levels. Simple and multiple regressions of soil physical and chemical properties on water retention at different suction levels were carried out as per the procedure described by Panse and Sukhatme (1995).

Table 1. General description of the soil samples collected from different agro-climatic zones of Maharashtra

Zone	Soil series	Place	Tehsil	District	Parent material	Soil type
II	Wadgaon	Wadgaon	Junner	Pune	Basaltic	Typic Haplustert
III	Shendwade	Shendwade	Sindkheda	Dhulia	Basaltic alluvium	Typic Haplustert
III	Rastapur	Kharekharjune	Ahmednagar	Ahmednagar	Basaltic alluvium	Typic Haplustert
III	Vadgaon-amli	Vadgaon-amli	Parner	Ahmednagar	Basaltic	Typic Haplustert
III	Otur	MPKV, Rahuri	Rahuri	Ahmednagar	Basaltic	Typic Haplustert
III	Nimone	MPKV, Rahuri	Rahuri	Ahmednagar	Basaltic	Typic Haplustert
III	Dholwad	MPKV, Rahuri	Rahuri	Ahmednagar	Basaltic	Typic Haplustept
III	Umbraj	MPKV, Rahuri	Rahuri	Ahmednagar	Basaltic	Udic Haplustert
III	Sawargaon	MPKV, Rahuri	Rahuri	Ahmednagar	Basaltic	Vertic Haplustept
III	Barshi	Kalegaon	Barshi	Sholapur	Basaltic	Typic Haplustert
III	Kandegaon	Kandegaon	Miraj	Sangli	Basaltic	Typic Haplustept
IVA	Tadpangari	Tadpangari	Parbhani	Parbhani	Basaltic plain	Typic Haplustert
IVA	Sayala	Sayala	Parbhani	Parbhani	Basaltic	Typic Haplustert
IVA	Ranjani	Ranjani	Parbhani	Parbhani	Basaltic	Typic Haplustert
IVB	Hated	Hated	Chopda	Jalgaon	Basaltic plain	Typic Haplustert
IVB	Hingona	Hingona	Chopda	Jalgaon	Basaltic	Typic Haplustert
VB	Aroli	Agri.College, Nagpur	Nagpur	Nagpur	Basaltic flood plains	Typic Haplustert
VB	Karla	Mehagaon	Nagpur	Nagpur	Basaltic	Typic Haplustert
VB	Linga	Bokaro	Nagpur	Nagpur	Basaltic	Typic Haplustert
VB	Kirnapur	Koradi	Nagpur	Nagpur	Old alluvium	Entic Haplustert

Table 2. Physical and Chemical Properties of the swell-shrink soils of Maharashtra

Soil series*	pH	EC dSm^{-1}	Organic carbon	$CaCO_3$	CEC	Exch. Ca+Mg	Exch. Na	Sand	Silt	Clay	Porosity	Surface area	Mean wt. diameter
			%		c mol kg^{-1}			%				m^2g^{-1}	mm
Wadgaon	7.9	0.11	0.69	05.5	69.5	59.1	5.3	12.4	17.6	70.0	59.2	578.7	0.6
Shendawade	8.0	0.14	0.62	06.6	57.8	51.0	5.4	24.6	14.6	60.8	52.8	358.6	0.7
Rastapur	8.3	0.65	0.46	14.4	62.9	53.9	2.6	23.9	12.3	63.8	57.3	452.5	0.5
Vadgaon-amli	8.2	1.39	0.55	13.7	61.8	52.7	3.6	24.9	12.6	62.5	56.5	421.4	0.5
Otur	8.4	0.18	0.58	13.6	62.1	52.8	4.5	23.9	12.7	63.4	56.9	436.2	0.5
Nimone	8.6	0.20	0.56	06.9	57.1	50.9	3.3	25.5	15.4	59.1	51.5	384.2	0.3
Dholwad	9.0	0.27	0.74	07.2	60.9	51.5	2.0	21.0	16.0	63.0	55.0	391.2	0.4
Umbraj	8.5	0.20	0.55	12.2	63.2	53.9	2.8	22.3	13.1	64.6	57.3	466.0	0.5
Sawargaon	8.6	0.21	0.47	05.5	67.4	54.9	4.0	16.5	14.3	69.2	58.5	490.3	0.6
Barshi	8.4	0.11	0.60	10.2	68.9	58.2	5.3	15.1	14.9	70.0	58.8	531.0	0.6
Kandegaon	8.8	0.22	0.61	10.0	74.5	63.5	6.0	12.6	15.0	72.4	59.7	605.0	0.8
Tadpangari	8.2	0.09	0.42	06.4	58.7	51.2	4.3	22.9	15.5	61.6	54.2	382.0	0.4
Sayala	8.2	0.08	0.59	08.5	61.2	52.3	2.9	21.8	16.1	62.1	55.8	407.3	0.5
Ranjani	8.6	0.12	0.55	06.6	56.6	50.3	3.1	27.1	13.2	59.7	51.6	352.2	0.3
Hated	8.4	0.15	0.55	05.0	66.0	54.2	3.8	18.1	13.9	68.0	58.6	478.4	0.6
Hingona	8.8	0.15	0.49	07.0	43.6	39.1	4.0	35.8	13.7	50.5	49.2	292.3	0.2
Aroli	8.3	0.14	0.53	01.3	54.8	49.9	0.9	31.7	12.2	56.1	50.9	342.5	0.2
Karla	7.5	0.07	0.60	02.2	58.0	51.0	3.9	24.7	15.8	59.5	53.8	370.0	0.4
Linga	8.5	0.09	0.52	04.8	50.0	45.2	2.9	31.6	13.8	54.6	49.6	312.4	0.1
Kirnapur	8.1	0.08	0.45	02.3	40.8	37.4	1.9	37.0	14.2	48.8	47.1	282.4	0.1

*Surface soil samples.

Table 3. Volumetric water contents (%) at various matric suction for the swell-shrink soils of Maharashtra

Soil series	0	10	20	33	40	50	80	100	200	300	400	800	1500
Wadgaon	91.7	71.0	58.0	52.8	49.4	46.7	44.6	43.1	38.2	34.0	31.1	29.4	28.0
Shendwade	75.4	58.1	47.6	39.2	36.9	34.7	32.6	30.7	27.9	25.5	23.5	21.9	20.4
Rastapur	82.5	64.4	49.9	41.3	39.4	37.1	36.0	34.5	31.5	28.7	26.3	23.8	21.7
Vadgaon-amli	79.2	61.0	48.8	39.8	37.6	35.5	33.4	32.7	29.8	27.1	24.6	22.6	20.7
Otur	79.1	62.7	49.3	40.4	38.3	36.1	35.1	33.7	30.8	28.1	25.8	23.6	21.4
Nimone	74.2	58.2	47.5	38.8	36.9	34.7	31.3	30.2	27.8	25.5	23.5	22.0	20.5
Dholwad	74.9	58.7	48.5	39.5	37.4	35.3	33.2	32.2	29.4	26.6	24.2	22.3	20.7
Umbraj	90.2	67.8	53.9	45.5	42.3	40.6	38.6	38.0	34.8	31.9	29.0	26.4	25.4
Sawargaon	89.8	70.9	55.4	48.7	45.5	42.9	41.9	40.6	35.0	31.8	29.0	27.4	26.1
Barshi	90.7	68.8	56.2	52.5	48.1	45.4	44.3	43.1	37.3	34.0	31.1	29.5	28.1
Kandegaon	93.7	79.5	65.3	56.8	52.4	48.5	46.5	45.6	41.5	36.6	33.3	31.4	30.2
Tadpangari	73.6	58.0	48.7	39.2	37.0	34.9	32.8	31.2	28.4	25.9	23.8	22.7	20.3
Sayala	77.8	59.8	48.6	39.8	37.6	35.5	33.5	32.6	29.7	27.0	24.5	22.5	20.8
Ranjani	70.6	55.8	43.8	37.7	33.8	31.6	30.1	28.7	26.2	23.7	20.7	20.4	19.6
Hated	91.5	70.5	55.9	46.1	43.7	42.2	40.1	39.1	36.0	32.8	30.1	29.1	24.9
Hingona	67.6	47.9	37.1	34.4	30.7	28.3	27.5	25.1	22.8	21.0	19.7	19.2	19.0
Aroli	71.3	52.0	42.6	37.1	33.9	31.7	30.0	28.1	25.3	23.0	21.1	20.2	19.5
Karla	73.8	57.9	48.3	39.2	37.0	34.8	33.3	31.1	28.3	25.8	23.7	22.0	20.2
Linga	69.0	49.6	39.0	35.7	31.9	29.7	28.7	25.6	23.1	21.2	19.8	19.3	19.1
Kirnapur	68.8	46.5	37.1	33.7	29.0	26.6	24.5	24.0	22.2	20.5	19.4	18.9	18.9

*Surface soil samoles

Results and Discussion

Water retention characteristics of different soils are presented in Table 3. The quantum of water held in the soils decreased with increase in suction. The rapid release of soil water being apparent between 0 and 33 kPa suction. The soils from Kandegaon, Barshi and Wadgaon series retained more water at all the suctions than all other soils studied due to higher clay content, high surface area and more exchangeable bases. On the other hand soils from Kirnapur series with low clay content retained lowest water at all the suction levels.The desorption curve suggest that most of the water i.e. 45-50 per cent was desorbed when matric suction increased from 0 to 33 kPa.

Wadgaon soil series in agro-climatic zone II retained 91.75 per cent water at saturation which remained 52.81 per cent at 33 kPa with net desorption of 42.79 per cent between 0-33 kPa and further declined to 27.97 per cent at 1500 kPa. Among the 10 soil series in agro-climatic zone III, saturation water content ranged between 74.24 (Nimone) and 93.72 (Kandegaon) per cent. Whereas, water retention at 33 and 1500 kPa ranged between 38.78 (Nimone) and 56.76 (Kandegaon), and 20.38 (Shendwade) and 30.20 (Kandegaon) per cent, respectively. On an average these soils desorbed 46.84 per cent of total water between 0 and 33 kPa suction. In agro-climatic zone IVA, water retention at saturation, 33 kPa and 1500 kPa ranged between 70.60(Ranjani) and 77.81 (Sayala), 37.73 (Ranjani) and 39.80 (Sayala), and 19.58 (Ranjani) and 20.82 (Sayala) per cent, respectively. Average desorption between 0 and 33 kPa in these soils was 47.39 percent of total water. Hated soil series retained 91.53, 46.14 and 24.86 per cent water at 0, 33 and 1500 kPa as compare to 67.58, 34.39 and 19.01 per cent by Hingona soil series in agro-climatic zone IVB.. On an average these two soils desorbed 49.35, per cent of total water between 0 and 33 kPa. Among four soil series in agro-climatic zone VB, water retention at 0,33, and 1500 kPa ranged between 68.85 (Kirnapur) and 73.80 (Karla), 33.75 (Kirnapur) and 39.24 (Karla), and 18.9 (Kirnapur) and 20.17 (Karla) per cent, respectively. Average desorption between 0 and 33 kPa through these soils was 48.5 per cent of the maximum water holding capacity of soil. While working on the clay soils of Dadra and Nagar Haveli, Challa and Gaikwad also reported the similar results.

Differences in water retention behaviour of different soil series may be attributed to their clay content, organic matter content and other soil physico-chemical properties.

Distribution of water in drainable (DW), available (AW) and residual (AW) water ranges is presented in Table 5. In these soils, the DW ranged between 32.87 and 45.39, AW between 14.85 and 26.56; and RW between 18.90 and 30.20 per cent, respectively. In Wadgaon series 38.94, 24.84 and 27.97 per cent water was distributed in DW,

Table 4. Distribution of soil-water (% by volume) in three different ranges

Soil series*	Drainable water	Available water	Residual water
Wadgaon	38.9	24.8	28.0
Shendwade	36.2	18.8	20.4
Rastapur	41.2	19.5	21.7
Vadgaon-amli	39.4	19.1	20.7
Otur	38.6	19.0	21.4
Nimone	35.5	18.3	20.5
Dholwad	35.3	18.8	20.7
Umbraj	44.6	20.1	25.4
Sawargaon	41.1	22.6	26.1
Barshi	38.2	24.4	28.1
Kandegaon	37.0	26.6	30.2
Tadpangari	34.4	18.9	20.3
Sayala	38.0	19.0	20.8
Ranjani	32.9	18.1	19.6
Hated	45.4	21.3	24.9
Hingona	33.2	15.4	19.0
Aroli	34.2	17.6	19.5
Karla	34.6	19.1	20.2
Linga	33.3	16.7	19.1
Kirnapur	35.1	14.8	18.9

*Surface soil samples.

Table 5. Functional relationship between soil-water content (Y in %) and matric suction (X in bars) for swell-shrink soils of Maharashtra

Soil series*	Regression equation
Wadgaon	$Y=42.9500X^{-0.1864}$
Shendwade	$Y=32.3165X^{-0.2024}$
Rastapur	$Y=35.2748X^{-0.1980}$
Vadgaon-amli	$Y=33.5032X^{-0.2016}$
Otur	$Y=34.5220X^{-0.1961}$
Nimone	$Y=32.1524X^{-0.2009}$
Dholwad	$Y=33.1167X^{-0.1994}$
Umbraj	$Y=38.6392X^{-0.1840}$
Sawargaon	$Y=40.2745X^{-0.1934}$
Barshi	$Y=42.3990X^{-0.1788}$
Kandegaon	$Y=46.1937X^{-0.1911}$
Tadpangari	$Y=32.6492X^{-0.2006}$
Sayala	$Y=33.4256X^{-0.1996}$
Ranjani	$Y=30.0908X^{-0.2043}$
Hated	$Y=39.9779X^{-0.1845}$
Hingona	$Y=27.0860X^{-0.1839}$
Aroli	$Y=29.5730X^{-0.1979}$
Karla	$Y=32.5355X^{-0.2033}$
Linga	$Y=27.8238X^{-0.1946}$
Kirnapur	$Y=26.1507X^{-0.1790}$

*Surface soil samples.

AW and RW ranges, respectively. Among 10 soil series in agro-climatic zone III; DW, AW ans RW ranged between 35.33 (Dholwad) and 44.63 (Umbraj), 18.30 (Nimone) and 26.56 (Kandegaon), and 20.38 (Shendwade) and 28.11 (Kandegaon) per cent, respectively. In agro-climatic zone IVA, water distribution ranged between 32.87 (Ranjani) and 38.01 (Sayala), 18.15 (Ranjani) and 18.90 (Tadpangari), and 19.58 (Ranjani) and 20.82 (Sayala) per cent in DW, AW and RW ranges, respectively. Distribution of water in Hated series under agro-climatic zone IVB was 45.39, 21.28 and 24.86 per cent in DW, AW and RW ranges, respectively. as compared to 33.19, 15.38 and 19.01 per cent in Hingona series. In 4 soil series of agro-climatic zone VB, water distribution ranged between 33.28 (Linga) and 35.10 (Kirnapur), 14.85 (Kirnapur) and 19.07 (Karla), and 18.90 (Kirnapur) and 20.17 (Karla) per cent in DW, AW and RW ranges, respectively.

In general 39.44 to 50.98 per cent of total water was distributed in DW and 26.10 to 32.22 per cent in RW. However, in AW range only 21.57 to 28.34 per cent of total water was distributed. Despite the high water retention, quantum of AW is less in these soils and hence these soils deserve specific attention towards crop and water management problems.

The empirical relationship between water content and matric suction in these soils are presented in Table 5. It is clear that ‘a’ values (intercept of matric suction to water content relationship) of the empirical relationship were higher in those soils which retained higher water throughout the range of matric suction as compare to the others, whereas, ‘b’ values (slope of matric suction to water content relationship) were in the reverse order. The values of ‘a’ and ‘b’ ranged between 26.1507 (Kirnapur) and 46.1937 (Kandegaon), and -0.2043 (Ranjani) and -0.1788 (Barshi), respectively in these swell-shrink soils. Higher ‘a’ values attributed to the presence of high amount of clay probably montmorillonitic, indicating higher water retention at any suction level.

Specific water capacity of these soils at six suction levels are presented in Table 6. It is apparent from the data that the soils with comparatively low clay content (e.g. Kirnapur) release water at a faster rate in low suction range whereas, the heavy textured soils (e.g. Kandegaon and Wadgaon) release at slower rate in the high suction range. Specific water capacity values were minimum near saturation and maximum at 1500 kPa. At a particular matric suction specific water capacity values were lowest for the soils with higher clay content and vice-versa.

In order to predict the water retention by these swell-shrink soils at saturation, 33 kPa and 1500 kPa, an attempt was made to develop simple and multiple regressions of water retention on physical and chemical properties of these soils. Among the various soil physical properties, per cent porosity was the most dominating parameter influencing water retention at saturation (Table 7) with

Table 6. Specific water capacity ($cm^3 cm^{-3} atm^{-1}$)of swell-shrink soils.

Soil series*	Suction (kPa.)					
	10	33	80	400	800	1500
Wadgaon	-123.00	-29.84	-10.43	-1.546	-0.679	-0.322
Shendwade	-104.23	-24.80	-8.55	-1.235	-0.537	-0.252
Rastapur	-110.14	-26.35	-9.12	-1.327	-0.578	-0.272
Vadgaon-amli	-107.40	-25.59	-8.83	-1.277	-0.555	-0.261
Otur	-106.33	-25.50	-8.84	-1.290	-0.563	-0.265
Nimone	-102.57	-24.45	-8.44	-1.222	-0.532	-0.250
Dholwad	-104.50	-24.96	-8.63	-1.252	-0.545	-0.257
Umbraj	-108.53	-26.40	-9.26	-1.377	-0.606	-0.288
Sawargaon	-121.59	-29.25	-10.17	-1.489	-0.651	-0.308
Barshi	-114.43	-28.01	-9.86	-1.479	-0.653	-0.311
Kandegaon	-137.07	-33.06	-11.52	-1.693	-0.742	-0.351
Tadpangari	-103.95	-24.79	-8.56	-1.240	-0.540	-0.254
Sayala	-105.64	-25.23	-8.72	-1.265	-0.551	-0.259
Ranjani	-98.40	-23.37	-8.04	-1.158	-0.503	-0.236
Hated	-112.76	-27.42	-9.60	-1.428	-0.628	-0.298
Hingona	-76.07	-18.51	-6.49	-0.965	-0.425	-0.202
Aroli	-92.30	-22.08	-7.65	-1.112	-0.485	-0.228
Karla	-105.67	-25.12	-8.65	-1.248	-0.542	-0.245
Linga	-84.78	-20.36	-7.07	-1.034	-0.451	-0.213
Kirnapur	-70.69	-17.30	-6.09	-0.913	-0.403	-0.192

*Surface soil samples.

Table 7. Simple and multiple regression of saturation water content (Y) with physical and chemical properties of swell-shrink soils.

Parameter	Regression equation	R^2
	Simple regression	
Sand (%)	Y = 103.057 - 1.5246X	0.89**
Silt (%)	——	—
Clay (%)	Y = -40.1334 + 1.7284X	0.93**
Surface area ($m^2 g^{-1}$)	Y = 14.80 + 0.125X	0.95**
Porosity (%)	Y = -96.54 + 2.988X	0.96**
Mean weight diameter (mm)	Y = 40.53 + 60.561X	0.94**
CEC (c $mol_{(p+)} kg^{-1}$)	Y = -9.911 + 1.2859X	0.91**
Exch. Ca + Mg (c $mol_{(p+)} kg^{-1}$)	Y = -18.938 + 1.6635X	0.85**
Exch. Na (c $mol_{(p+)} kg^{-1}$)	Y = 50.13 + 4.6353X	0.51*
Exch. K (c $mol_{(p+)} kg^{-1}$)	——	—
Organic carbon (%)	——	—
$CaCO_3$ (%)	Y = 56.044 + 1.4582X	0.48*
pH	——	—
EC (dSm^{-1})	——	—
	Multiple regression	
	$Y = -34743.0 + 348.98X_1 + 347.013X_2 + 346.047X_3$	0.91
	$Y = -83.9692 - 0.03464X_1 + 0.4181X_2 + 0.0784X_4 + 2.099X_5$	0.96
	$Y = 17.0462 + 3.32X_6 - 2.90952X_7 + 0.46531X_8$	0.89

X_1 = Clay (%); X_2 = Sand (%); X_3 = Silt (%); X_4 = Surface area ($m^2 g^{-1}$); X_5 = Porosity (%); X_6 = CEC (c $mol_{(p+)} kg^{-1}$); X_7 = Exch. Ca+Mg (c $mol_{(p+)} kg^{-1}$); X_8 = Exch. Na (c $mol_{(p+)} kg^{-1}$)

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

Table 8. Simple and multiple regression of water content at 33 kPa (Y) with physical and chemical properties of swell-shrink soils

Parameter	Regression equation	R^2
	Simple regression	
Sand (%)	$Y = 59.67 - 1.0231X$	0.93**
Silt (%)	——	—
Clay (%)	$Y = -34.41 + 1.1275X$	0.94**
Surface area (m^2g^{-1})	$Y = 0.7276 + 0.0833X$	0.99**
Porosity (%)	$Y = -65.60 + 1.8466X$	0.92**
Mean weight diameter (mm)	$Y = 18.1025 + 39.7447X$	0.95**
CEC (c $mol_{(p+)}kg^{-1}$)	$Y = -14.7906 + 0.8404X$	0.92**
Exch. Ca + Mg (c $mol_{(p+)}kg^{-1}$)	$Y = -22.44 + 1.1212X$	0.89**
Exch. Na (c $mol_{(p+)}kg^{-1}$)	$Y = 22.4709 + 3.5739X$	0.61*
Exch. K (c $mol_{(p+)}kg^{-1}$)	——	—
Organic carbon (%)	——	—
$CaCO_3$ (%)	——	—
pH	——	—
EC (dSm^{-1})	——	—
	Multiple regression	
	$Y = -20304.7 + 203.85X_1 + 202.63X_2 + 202.68X_3$	0.97
	$Y = 2.9093 + 0.04756X_1 - 0.0585X_2 + 0.0767X_4 + 0.01729X_5$	0.97
	$Y = -6.08815 + 1.32632X_6 - 0.80293X_7 + 1.02221X_8$	0.88

X_1 = Clay (%); X_2 = Sand (%); X_3 = Silt (%); X_4 = Surface area (m^2g^{-1}); X_5 = Porosity (%); X_6 = CEC (c $mol_{(p+)}kg^{-1}$); X_7 = Exch. Ca+Mg (c $mol_{(p+)}kg^{-1}$); X_8 = Exch. Na (c $mol_{(p+)}kg^{-1}$)
* Significant at $P = 0.05$; ** Significant at $P = 0.01$

Table 9. Simple and multiple regression of water content at 1500 kPa (Y) with physical and chemical properties of swell-shrink soils

Parameter	Regression equation	R^2
	Simple regression	
Sand (%)	$Y = 31.409 - 0.5329X$	0.90**
Silt (%)	——	—
Clay (%)	$Y = -17.68 + 0.5886X$	0.92**
Surface area (m^2g^{-1})	$Y = 0.3653 + 0.442X$	0.98**
Porosity (%)	$Y = -34.11 + 0.9668X$	0.90**
Mean weight diameter (mm)	$Y = 9.6536 + 0.9332X$	0.94**
CEC (c $mol_{(p+)}kg^{-1}$)	$Y = -7.198 + 0.4347X$	0.89**
Exch. Ca + Mg (c $mol_{(p+)}kg^{-1}$)	$Y = -10.914 + 0.5752X$	0.85**
Exch. Na (c $mol_{(p+)}kg^{-1}$)	$Y = 11.9611 + 8805X$	0.60*
Exch. K (c $mol_{(p+)}kg^{-1}$)	——	—
Organic carbon (%)	——	—
$CaCO_3$ (%)	——	—
pH	——	—
EC (dSm^{-1})	——	—
	Multiple regression	
	$Y = -13825.2 + 138.92X_1 + 138.03X_2 + 138.013X_3$	0.89
	$Y = 1.60767 - 0.01955X_1 + 0.01108X_2 + 0.0475X_4 + 0.0305X_5$	0.96
	$Y = -1.1665 + 0.7966X_6 - 0.5766X_7 + 0.58033X_8$	0.84

X_1 = Clay (%); X_2 = Sand (%); X_3 = Silt (%); X_4 = Surface area (m^2g^{-1}); X_5 = Porosity (%); X_6 = CEC (c $mol_{(p+)}kg^{-1}$); X_7 = Exch. Ca+Mg (c $mol_{(p+)}kg^{-1}$); X_8 = Exch. Na (c $mol_{(p+)}kg^{-1}$)
* Significant at $P = 0.05$; ** Significant at $P = 0.01$

R^2=0.96. Other soil physical properties viz. per cent clay(R^2=0.936), per cent sand(R^2=0.896), surface area(R^2=0.956) and mean weight diameter(R^2=0.940) influenced the saturation water content significantly, however, per cent silt showed a non significant response. Multiple regression revealed that the per cent clay, among the particle sizes influenced saturation water content to the great extent(R^2=0.914). However, per cent porosity was the most dominantly influencing physical property (R^2=0.964). Among various chemical properties, CEC influenced water retention at saturation to the great extent (R^2=0.911) followed by exchangeable Ca+Mg. Multiple regression of chemical properties on water retention at saturation revealed that the CEC was most dominating property for predicting water retention at saturation.

At 33 kPa suction, surface area showed maximum influence (R^2=0.988) on water retention among the physical properties (Table 8). Interactive effects of per cent sand, silt and clay showed that the per cent clay (R^2=0.922) had the maximum influence on water retention at 33 kPa. Multiple regression of the different physical properties on water retention at 33 kPa showed that the surface area was the most dominating factor (R^2=0.978). Among the chemical properties CEC was (R^2=0.925) the major factor when analysed for individual as well as combined contribution.

At 1500 kPa suction, surface area was the most effective (R^2=0.98) individual physical parameter (Table 9). Per cent clay (R^2=0.89) was most effective among the particle sizes. Multiple regression showed that the surface area (R^2=0.961) was the most influencing physical property as compared to the others. Among various chemical properties, the CEC (R^2=0.892) had the maximum influence on water retention at 1500 kPa. These findings are in agreement with the results reported by Warale (1975) on similar soils. At 1500 kPa, Biswas and Ali (1967) reported higher dependence of water retention on clay content than that of the organic carbon in 46 black soils.

References

Biswas, T.D. and Ali, M.(1967). Influence of organic carbon and clay content of the soils on the permanent wilting percentage. *Indian J. Agric. Sciences.* 37: 322-331.

Bruce, R.R. and Luxmoore, R.J. (1986). Water retention: Field methods. In 'Methods of Soil Analysis' Part I, Ed. Klute, A. Agron. Monogr. No. 9 pp 663-686.

Challa, O. and Gaikwad, S.T.(1987). Water retention characteristics of major soils of Dadra and Nagar Haveli. *J.Ind. Soc. Soil Sci* 35:118-120.

Day,P.R.. G.H.Bolt and D.M. Anderson (1967). Irrigation of Agricultural Lands. Agronomy monogram No. 11. Madison. Wisconsin, U.S.A.

Gupta,R.P, P.D.Sharma, C.L.Acharya and B.R.Tripathi (1983).Water retention characteristics of some soil profiles under different bio and climosequences. *J. Ind. Soc. Soil Sci* 31:458-463

Jackson, M.L. (1973). *Soil chemical analysis.* Prentice Hall of India Pvt. Ltd., New Delhi. pp. 1-498.

Ohu, J.O., G.S.V. Raghvan, S. Prashier and G. Mehuys (1987). Prediction of water retention characteristics from soil compaction data and organic matter content. *J. Agril. Engg. Res 3*8:37-35.

Page, A.L., R.H.,Miller and D.R.Keeney (1982). Methods of Soil Analysis. Agronomy monogram No. 9, Madison, Wisconsin, U.S.A.

Panse, V.G.and P.V. Sukhatme (1995). Statistical methods for agricultural workers. I.C.A.R. Publication.

Rijov, S.N. (1973). Water, plant growth and irrigation requirement. In V.A. Kovda et al. (Eds) 'Irrigation Drainage and Salinity" An International Source Book, FAO/UNESCO, Hutchinson and Co. Ltd,. London.

Warale, P.J. (1975). Water retention properties of the soils of central farm, M.P.K.V. Rahuri. M.Sc. Thesis, M.P.K.V. Rahuri.

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Online reference: FAO 2008. *FAO Land and plant nutrition management service.* http://www.fao.org/ag/agl/agll/spush.

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