

DISSEMINATION OF TECHNOLOGIES FOR ROOTZONE SALINITY MANAGEMENT AND ON-FARM WATER MANAGEMENT IN THE LOWER INDUS BASIN OF PAKISTAN^[1]

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ABSTRACT

Under the arid conditions prevailing in the Lower Indus Basin, crop production is only possible under irrigated agriculture. The irrigation system of Pakistan is largely unlined, which means that seepage losses from canals and watercourses reduce the water available for crop production. Farmers installed shallow tubewells to increase their irrigation water supplies. Over the past years rainfall has been minimal in Pakistan and this has reduced the availability of canal water. As a result the need for tubewell water increased and the number of private tubewells increased exponentially. This caused the watertable to fall dramatically and farmers are pumping groundwater from greater depth. However, in the Indus Basin groundwater salinity is increasing with depth and farmers are pumping more and more saline water, which they use to irrigate their fields. This development has reached alarming dimensions. Current estimates put the number of tubewells in Pakistan at around 600,000. Under the National Drainage Program the Lower Indus Water Management and Reclamation Research (LIM) Project at Hyderabad is conducting experiments on farmers fields for dissemination of technologies to grow crops with saline water without destroying soil structure so that the practice remains sustainable. The experimental work involves the application of amendments, use of proper fertilizers, water management technology using laser-controlled precision land leveling as well as lining of watercourses to reduce seepage losses. This will increase availability of good quality water for crop production. This paper reports on preliminary results. Farmers meetings and field days are being held in the area to disseminate findings and farmers show great interest in the results.

Tentative findings indicate that groundwater of poor quality containing upto 2,000 ppm total salts can be used for crop production on these soils, provided amendments like farm yard manure and sugar mill filter cake (Press mud) are used. Without the use of amendments, irrigation with this saline water will deteriorate soil structure and reduce crop yields. Experiments and dissemination to farmers continue and this project will be completed by mid 2004.

1 INTRODUCTION

Agriculture depends upon irrigation and most of crop production is attributed to irrigated agriculture. Due to arid and semi-arid climatic conditions, irrigation is central to irrigated agriculture. Pakistan has developed one of the largest contiguous irrigation systems of the world which is confronted with problems of waterlogging and salinity and water shortages. The irrigated agriculture in Pakistan offers conducive environment for occurrence of waterlogging and salinity due to flat topography and arid to semi-arid conditions. The evaporation rates vary between 2.5 mm/day to 13 mm/day with an annual average of 2400 mm. These climatic conditions are favourable for capillary salinization. The irrigation system without adequate drainage facilities has resulted in rising water tables. The rise in water tables has been followed by salinization and sodification of the surface soils. In the country vast areas have been affected by moderate to strong salinity and sodicity problems. This has led to a decrease in national agricultural output to meet the population needs growing at the rate of about 2.15% per annum (Anonymous, 2000).

Further due to scarcity of canal water supplies, dependence on ground water use has increased rapidly. In many canal water shortage areas, farmers often supplement it with ground water resources of which the quality varies from useable to hazardous. Generally farmers give little attention towards the quality of underground water being used and as such its discriminate use without adopting proper management practices deteriorates the physical and chemical properties of the soil. The available ground water resources in the Indus Plain are in general of inferior quality and deteriorate the physical and chemical status of the soil as well as crop growth. About 50% of the underground resources can be used for crop production by adopting appropriate technology, while remaining 50% is hazardous (Malik, et al; 1984).

The magnitude of problem warrants all out efforts for improvement, management and reclamation of salinized soil. The role of appropriate technology in agriculture and allied sectors is more crucial in SAARC countries as more than half of the national income derived from agriculture (Kabir, 1998). Hence an integrated package of fertilizer and amendments use to avert the deleterious effects of soil and water salinity need to be developed and disseminated to farmers. The use of fertilizers with proper dose and combination play an important role in increasing crop yields (Braun et al; 1983). Soil condition is an important consideration especially for the selection of fertilizers materials and results in higher efficiency (Saleem, 1992).

Plants are generally inefficient in uptake of soil N due to losses from NH₃ volatilization, leaching and de-nitrification. Efficiency can be improved by properly time fertilization or by enhancing plant absorption of N. Ammonium toxicity is particularly deleterious to young seedling and can limit plant yields (Fenn et al; 1991). Plant yields in calcareous soils where Ca²⁺ was applied with Urea

were increased compared to yields with Urea alone, NH_4NO_3 , or other common N fertilizers (Fenn, 1986; Fenn et al; 1987).

Organic matter (FYM, green manure or natural manure) aid in reclamation process by releasing Ca from CaCO_3 present in calcareous soils (Ahmed and Chaudhry, 1997). Various researchers reported that addition of organic matter as FYM/green manure could facilitate the hydraulic conductivity which can prolong the appearance of adverse effects of high EC_w on soil and crops (Ghafoor et al; 1997 a,b). The application of press mud to a saline sodic soil significantly reduce soil SAR and increase water infiltration and crop yields of Wheat and Cotton with use of high SAR water (Haider and Hussain, 1976 and Chand et al; 1977).

Considerable research work has been carried out for utilizing the saline land and water resources in economical and sustainable manner. The need for disseminating these technologies to farmers at their doorstep for enhancing crop production is reported by Bandyopadhyay et al (1998). To study the prospects and possibility of safe use of poor quality ground water by farmers on sustainable basis, a study “Dissemination of Technologies for Rootzone Salinity Management and On-Farm Water Management in the Lower Indus Basin of Pakistan” was initiated on farmers’ field at Dhoro Naro Minor of LBOD Stage-I Project area near Nawabshah.

The objectives of the study are to:

- Demonstrate the effect of amendments and FarmYard Manure in conjunction with saline irrigation water on soil properties and crop production.
- Select best suited types and combination fertilizers for crop production with saline irrigation water.
- Disseminate the improved technologies of re-alignment of watercourse, management of surface irrigation water, precision land leveling and redesigning of farm layout.

2 MATERIAL AND METHODS

2.1 Location of Study Area

The study is being carried out in the Dhoro Naro Minor command located in the east of Nawabshah City in Nawabsahah Component of LBOD Stage-I. The total Gross Command Area (GCA) is about 6098 hectares (15067 acres) out of which Culturable Command Area (CCA) is 5416 hectares (13382 acres). It off takes from the Gajrah Branch of Nasrat Branch that off takes from Rohri Canal. The total length of the minor is 10.39 km. The designed, discharge of the minor is 51.62 cusecs with 25 watercourses off taking from both the sides of the minor. The Dhoro Naro Minor command area is a nondescript stretch of land, about 17 kilometers long and roughly 7 kilometers wide. As this area is situated at the intersection of Nawabshah and Sanghar Districts, therefore, from an administrative point of view, it is divided into two districts; but, from an irrigation point of view, it falls in the Nawabshah Division. The salient features of the study area are presented in Table 1.

Table 1 Salient Features of the Dhoro Naro Minor

Irrigation	
Off take RD	91.4 (Gajrah Branch)
Designed Discharge at Head-Regulator	51.62 cusecs
Length of Minor	10.4 km
Total Length of Watercourses	77.8 km
Number of outlets	25
Number of lined Watercourses	16
Number of unlined Watercourses	09
Culturable Command Area (CCA)	13,382 acres
Gross Command Area (GCA)	15,067 acres
Drainage	

Number of saline Tubewells	07
Number of private Tubewells	more than 153
Total Length of Disposal Channel	km
Population	
Population	19822
Number of potential Water Users	504
Tenants (Share Croppers)	694
Number of Villages	147
Number of Households	2468
Major Communities	Jamali, Khaskheli, Syed, Zardari, Brohi, Arain, Gupchani, Shar, Mughari, Keerio, etc.
Languages of the area	Sindhi, Siraiki, Punjabi, Balochi & Brahvi
Cropping Pattern	
Kharif	Cotton, Sugarcane, Fodder
Rabi	Wheat, Sugarcane, Oil Seed, Vegetables, Fodder

2.2 Climate

The climate of the command area is extremely hot in the summer season, mostly in June and July, but is cold during winter. In the summer season, days remain very hot, sometimes temperatures pass 50 degrees centigrade, but in the night, mostly fast winds blow from the South; hence, nights are charming in the open air, while inside the house the atmosphere remains hot. The climate is suitable for all major crops such as cotton, wheat, chilies, sugarcane, oil seeds, bananas, etc.

Monthly rainfall during summer is between 45 and 55 millimeters, which is slightly more than in the northern part of the Sindh Province, while the winter season is particularly dry (IIMI, 1997).

2.3 Irrigation Resources

The main source of irrigation water is canal. But at the same time, there are more than 153 private tubewells which are being used during periods of water shortage. The tubewell water is being used by mixing with canal water when available because tubewell water contains salt concentrations ranging between 371 ppm and 8857 ppm. otherwise they use it as such just to save their standing crop.

There are water shortages at the tail of the minor, as well as on the tails of the watercourses. Despite the fact that there is water shortage, canal water is also wasted. The water wastage is mainly due to unreliable water supply, seepage losses, field application losses, deep percolation, evaporation due to an arid and hot climate, unlined watercourses, over and frequent irrigation.

2.4 Experimental Work

The experimental work was started during April, 2001 on farmer's fields in the command of Dhoro Naro Minor. The experimental work involves the application of amendments on two plots with size of 0.4 hectares on two watercourses, use of proper fertilizers on size of 0.4 hectares plots each on normal and saline soil on two separate watercourses and water management technology on separate watercourse. For experimental and demonstration purpose 5 out of 25 watercourses were selected. The soils were sandy loam with moderate salinity. Crop rotation used was Cotton-Wheat-Cotton. The following amendment treatments were tested with three replications and Randomized Complete Block Design:

- Treatment 1 -No amendment and irrigation with canal water (control)
- Treatment 2 -Farm Yard Manure @ 25 tons/ha and irrigation with tubewell water (up to 2000 ppm).
- Treatment 3 -Press Mud (Sugar mill filter cake) @ 25 tons/ha and irrigation with tubewell water (upto 2000 ppm).
- Treatment 4 -No amendment and irrigation with tubewell water (upto 2000 ppm).

The fertilizer treatments tested were Urea+DAP (control), Ammonium Nitrate + DAP and Ammonium Sulphate + Nitrophos. The parameters studied were soil characteristics (EC_e, SAR & pH) at 0-15, 15-30, 30-60, 60-90 and 90-120, soil infiltration rates by using Standard Ring Method (Aronovici, 1955) and crop yields at various stages. EC_e, SAR and pH were measured according to

the method described by US Salinity Laboratory Staff (1954). About 10 hectare plot was precisely leveled with laser controlled equipment and about 325 meter section of watercourse was lined to reduce water losses and increase water availability.

Dissemination plan has been framed for the end users which includes demonstration of experiments, individual/group farmers meetings and discussion, farmer's day and preparation and distribution of leaflets, pamphlets, and brochures regarding tested technologies. At regular intervals the process of dissemination is underway and farmers are showing keen interest in the various interventions for saline water use.

3 RESULTS AND DISCUSSION

3.1 Role of Amendments Experiment

3.1.1 Changes in Infiltration Rate of Soil

The Calcium Bicarbonates in solution form in irrigation waters tends to form relatively insoluble Calcium Carbonates which produces cement like calcite deposits in the soil. Consequently, Calcium is progressively lost in water while the Sodium remains in solution due to which Sodium to Calcium ratio increases in the water moving in the soil. The dominance of Sodium decreases the porosity of soil resulting in the reduction in soil infiltration rate, soil aeration and leaching capability of irrigation water. These reductions in soil permeability due to use of poor quality water can lead to salt accumulation unless otherwise managed through amendments.

The changes in infiltration rate of soil over the seasons are given in Table 2 & 3. The initial average infiltration rate of experimental plots at start of Kharif (season 15 April to 15 October) 2001 was 13.7 cm/6 hours at watercourse 3R and 12.0 cm/6 hours at watercourse 1BL.

At the end of the season (Kharif 2002), the 51 percent highest increase in infiltration rate over 2 years period was recorded in the plots where press mud was applied and irrigation were given with tubewell water at watercourse 3R whereas at watercourse 1BL, highest increase of 79% infiltration rate was recorded in treatment plot where Farm Yard Manure @ 25 tons/ha was applied with tubewell water. The results are in conformity with Ghafoor et al; (1997a, b) and Haider and Hussain (1976). The infiltration rates recorded at the harvest of Wheat crop Rabi (15 October to 15 April) 2001-02 are lower at both sites as compared to Kharif crop. The increase in infiltration rates seems to be attributed to addition of Cotton crop residue in the soil and due to low soil moisture contents. The post Rabi 2002-2003 infiltration measurement may further support this hypothesis.

Table 2 Soil infiltration rate (cm/6 hrs) as affected by different treatments at watercourse 3R.

Treatment	Initial Pre-Cotton 2001	Post Cotton 2001	Post Wheat 2001-02	Post Cotton 2002	Change (%)
No Amendments and irrigations with canal water (control). (T-1)	13.7	19.2	6.4	14.0	+2
Farm Yard Manure @ 25tons/ha and irrigation with tubewell water. (T-2)	13.7	19.8	11.7	20.0	+46
Press Mud @ 25 tons/ha and irrigation with tubewell water. (T-3)	13.7	18.7	9.8	20.7	+51
No Amendments and irrigation with tubewell water. (T-4)	13.7	17.0	8.5	18.4	+34

Table 3 Soil infiltration rate (cm/6 hrs) as affected by different treatments at watercourse 1BL.

Treatment	Initial Pre-Cotton	Post Cotton 2001	Post Wheat 2001-02	Post Cotton 2002	Change (%)
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	2001				
No Amendments and irrigations with canal water (control). (T-1)	12.0	14.3	6.7	14.4	+20
Farm Yard Manure @ 25tons/ha and irrigation with tubewell water. (T-2)	12.0	16.0	7.4	21.5	+79
Press Mud @ 25 tons/ha and irrigation with tubewell water. (T-3)	12.0	13.3	7.1	14.2	+18
No Amendments and irrigation with tubewell water. (T-4)	12.0	13.3	5.8	14.1	+17

3.1.2 Changes in Electrical Conductivity (ECe) of Soil

The ECe of soil profile is based on the movement of soluble salts with water in the soil matrix. If the movement of water is restricted by soil crusting, hardening of soil layers, inadequate drainage etc. the soil salinity is developed and as such ECe is increased and vice versa. On the other hand if the soil environment facilitates proper leaching, the ECe could be managed even with marginal quality irrigation water.

The bench mark ECe of study was determined before sowing of Cotton crop during Kharif 2001 and it was higher at upper depths than the lower depths. Depending on the quality of water used (tubewell and canal) and different amendments, the different treatments showed variable behaviour in the trend of ECe during the study (Table 4 & 5). The depth-wise trend of initial ECe at watercourse 3R shows gradual decrease up to 30-60 cm depth where it is almost of the same level as in 60-90 cm depth. At watercourse 1BL, the initial ECe is highest at 0-15 cm depth, followed by 60-90 cm depth and almost equal for 15-30 cm and 30-60 cm depth.

The data shows trend of increase in ECe at the end of Post Wheat 2001-02 at almost all the depths in all treatments at both the sites except T-3, where there is 34% decrease at 0-15 cm depth at watercourse 3R. The increase of ECe at treatment where canal water has been applied seems to be due to canal water shortages. In the absence of canal supplies some time tubewell water has to be applied for survival of crop.

Table 4 Electrical conductivity (Ece dS/m) of soil as affected by different treatments at watercourse 3R.

Treatment	Depth (cm)	Initial Pre-Cotton 2001	Post Cotton 2001	Post Wheat 2001-02	Change (%)
No Amendments and irrigations with canal water (control). (T-1)	0-15	4.7	11.3	5.4	+14.9
	15-30	2.9	10.8	3.6	+24.1
	30-60	1.7	3.6	2.7	+58.8
	60-90	1.7	2.7	2.2	+29.4
Farm Yard Manure @ 25tons/ha and irrigation with tubewell water. (T-2)	0-15	4.7	8.4	6.4	+36.2
	15-30	2.9	7.9	4.5	+55.2
	30-60	1.7	5.5	3.4	+100.0
	60-90	1.7	3.5	2.6	+52.9
Press Mud @ 25 tons/ha and irrigation with tubewell water. (T-3)	0-15	4.7	7.5	3.1	-34.0
	15-30	2.9	5.6	2.9	0.0
	30-60	1.7	4.2	2.5	+47.1
	60-90	1.7	4.1	2.1	+23.5
No Amendments and irrigation with tubewell water. (T-4)	0-15	4.7	7.8	5.2	+10.6
	15-30	2.9	10.6	5.4	+86.2
	30-60	1.7	5.3	2.9	+70.6
	60-90	1.7	2.3	2.3	+35.3

Table 5 Electrical conductivity (Ece dS/m) of soil as affected by different treatments at watercourse 1BL.

Treatment	Depth (cm)	Initial Pre-Cotton 2001	Post Cotton 2001	Post Wheat 2001-02	Change (%)
No Amendments and irrigations with canal water (control). (T-1)	0-15	2.9	5.4	4.5	+55.2
	15-30	1.9	5.0	5.3	+178.9
	30-60	2.0	4.3	3.7	+85.0
	60-90	2.3	3.6	2.2	-4.3
Farm Yard Manure @ 25tons/ha and irrigation with tubewell water. (T-2)	0-15	2.9	4.7	4.1	+41.4
	15-30	1.9	5.7	4.9	+157.9
	30-60	2.0	4.0	4.1	+105.0
	60-90	2.3	4.2	2.5	+8.7
Press Mud @ 25 tons/ha and irrigation with tubewell water. (T-3)	0-15	2.9	4.5	3.8	+31.0
	15-30	1.9	3.9	4.2	+121.1
	30-60	2.0	4.6	4.3	+115.0
	60-90	2.3	4.1	3.1	+34.8
No Amendments and irrigation with tubewell water. (T-4)	0-15	2.9	5.5	3.9	+34.5
	15-30	1.9	4.0	5.6	+194.7
	30-60	2.0	6.1	4.7	+135.0
	60-90	2.3	3.6	2.9	+26.1

3.1.3 Changes in Sodium Adsorption Ratio of Soil

The soil SAR values for different periods as affected by different treatments are given in Table 6 & 7. At the initial stage the SAR in 15-30 cm depth at watercourse 3R were higher in almost all the plots whereas it lowered with increasing depth. At the end of Wheat 2001-02 crop the SAR values have been decreased in the upper layer in all the treatments except T-3. The highest decrease was recorded in the 0-15 cm depth in T-1. At watercourse 1BL the SAR in the upper layer 0-15 cm depth has increased in all the treatments. The SAR level is well below the critical level and there are no signs of sodicity.

Table 6 Sar of soil as affected by different treatments at watercourse 3r.

Treatment	Depth (cm)	Initial Pre-Cotton 2001	Post Cotton 2001	Post Wheat 2001-02	Change (%)
No Amendments and irrigations with canal water (control). (T-1)	0-15	3.8	8.0	2.2	-42.1
	15-30	4.6	8.2	3.6	-21.7
	30-60	3.4	4.5	3.9	+14.7
	60-90	3.6	4.8	2.1	-41.7
Farm Yard Manure @ 25tons/ha and irrigation with tubewell water. (T-2)	0-15	3.8	7.0	4.2	+10.5
	15-30	4.6	7.3	3.8	-17.4
	30-60	3.4	5.2	4.0	+17.6
	60-90	3.6	3.8	3.3	-8.3
Press Mud @ 25 tons/ha and irrigation with tubewell water. (T-3)	0-15	3.8	6.4	4.8	+26.3
	15-30	4.6	5.9	5.7	+23.9
	30-60	3.4	5.2	3.3	-11.8
	60-90	3.6	4.2	3.2	-11.1
No Amendments and irrigation with tubewell water. (T-4)	0-15	3.8	7.1	2.9	-23.7
	15-30	4.6	8.9	3.9	-15.2
	30-60	3.4	5.1	5.0	+47.1
	60-90	3.6	3.5	5.3	+47.2

Table 7 Sar of soil as affected by different treatments at watercourse 1bl.

	Depth	Initial	Post	Post Wheat	Change
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Treatment	(cm)	Pre-Cotton 2001	Cotton 2001	2001-02	(%)
No Amendments and irrigations with canal water (control). (T-1)	0-15	2.3	4.7	4.2	+82.6
	15-30	3.1	3.4	2.8	-9.7
	30-60	2.0	3.2	2.5	+25.0
	60-90	7.4	3.3	3.5	-52.7
Farm Yard Manure @ 25tons/ha and irrigation with tubewell water. (T-2)	0-15	2.3	4.9	3.6	+56.5
	15-30	3.1	5.0	3.4	+ 9.7
	30-60	2.0	4.3	1.9	-5.0
	60-90	7.4	3.5	2.1	-71.6
Press Mud @ 25 tons/ha and irrigation with tubewell water. (T-3)	0-15	2.3	4.8	2.9	+26.1
	15-30	3.1	4.0	3.0	-3.2
	30-60	2.0	4.9	2.2	+10.0
	60-90	7.4	6.3	2.8	-62.2
No Amendments and irrigation with tubewell water. (T-4)	0-15	2.3	6.1	3.6	+56.5
	15-30	3.1	4.2	3.9	+25.8
	30-60	2.0	3.6	2.7	+35.0
	60-90	7.4	4.2	4.0	-45.9

3.1.4 Tubewell Water Quality

Tubewell water is being used for irrigation in all the treatments except control. The determination of its quality is important to know the effects on crop response. The quality of tubewell water is changing over time depending on the running time, as most of the tubewells are shallow. The tubewell water EC ranges from safe limits less than 1000 ppm and over the season it sometimes reach up to 4000 ppm which becomes hazardous and mixing with canal water becomes essential. The results of water quality are given in Table 8 to 10.

Table 8 Quality of tubewell water used for irrigation (Kharif 2001)

Irrigation	Date	pH	ECw Micromhos/cm	TDS (ppm)	SAR
Watercourse 3R					
I	15.06.2001	7.8	2900	1856	3.7
II	22.06.2001	7.8	4600	2944	6.7
III	06.07.2001	8.0	5000	3200	6.1
IV	20.07.2001	8.0	6000	3840	6.0
Watercourse 1BL					
I	01.07.2001	7.9	4200	2688	4.9
II	22.07.2001	7.8	4200	2687	4.9

Table 9 Quality of tubewell water used for irrigation during rabi 2001-02.

Irrigation	Date	pH	ECw Micromhos/cm	TDS (ppm)	SAR

Watercourse 3R					
I	06.12.2001	8.0	550	352	1.06
II	16.01.2002	8.0	3700	2368	3.57
III	30.01.2002	8.0	4300	2752	4.00
IV	15.02.2002	8.0	1100	704	1.81
Watercourse 1BL					
I	11.12.2001	7.8	4800	3072	3.10
II	06.01.2002	7.8	6500	4160	4.89
III	09.02.2002	7.8	6800	4352	5.11

Table 10 Quality of tubewell water used for irrigation during Kharif 2002.

Irrigation	Date	pH	ECw Micromhos/cm	TDS (ppm)	SAR
Watercourse 3R					
I	03.12.2002	8.0	1100	704	0.9
II	28.12.2002	8.0	1200	768	2.0
Watercourse 1BL					
I	08.12.2002	8.0	1800	1152	3.58
II	22.12.2002	8.0	3700	2368	4.32

3.1.5 Effect of Treatments on Crop Yields

The yield data for two season Cotton crop (Kharif 2001 & 2002) and one season Wheat crop for Rabi 2001-02 is given in Table 11 & 12. The data of Seed Cotton yield (Kharif 2001) at watercourse 3R indicate that the highest Seed Cotton yield of 1239 kg/ha was obtained from T-2 where Farm Yard Manure @ 25 tons/ha was applied with tubewell water which is followed by T-1. Seed Cotton yield of 1197 was achieved where only canal water was applied. The Seed Cotton yield of 1062 kg/ha was noted from T-3 where Press Mud was used with tubewell water irrigations. The lowest Seed Cotton yield of 767 kg/ha was produced from T-4 where all irrigations were made by tubewell water. It is further added that 4% increase has been noticed in Seed Cotton yield in T-2 which is followed by T-1 whereas 11% and 36% yield decrease has been observed in T-3 and T-4 respectively as compared to T-1.

The yield data of Seed Cotton at watercourse 1BL indicate that the maximum Seed Cotton yield of 1074 kg/ha was obtained from T-2 where Farm Yard Manure @ 25 tons/ha was applied with tubewell water which is followed by T-1. Seed Cotton yield of 1060 kg/ha was achieved where only canal water was applied. The Seed Cotton yield of 950 kg/ha was noted from T-3 where Press Mud was used with tubewell water irrigations. The lowest Seed Cotton yield of 759 kg/ha was produced from T-4 where all irrigations were applied with tubewell water. It is further added that 1% yield has been increased in T-2 which is followed by T-1 where all irrigations were applied with canal water (control). 10% and 28% yield was decreased in T-3 and T-4 respectively when compared with T-1.

During Kharif 2002, at watercourse 3R highest Cotton yield was obtained from T-2 plot followed by T-1 whereas at watercourse 1BL, control plot gave highest yield followed by T-2.

The highest Wheat grain yields of 5345 and 5525 kg/ha were obtained during Rabi 2000-01 at watercourse 1BL and 3R

respectively from the treatment T-1 where canal water was applied. The next higher yields were 4815 and 4630 kg/ha at watercourse 1BL and 3R, respectively from the treatment T-2 where FarmYard Manure was applied. The lowest yields were obtained from the treatment T-4 where tubewell water was applied.

Table 11 Crop yield (kg ha⁻¹) as affected by different treatments at watercourse 3R.

Treatment	Cotton				Wheat	
	Kharif 2001	Change over control (%)	Kharif 2002	Change over control (%)	Rabi 2001-02	Change over control (%)
No Amendments and irrigations with canal water (control). (T-1)	1197	-	1100	-	5525	-
Farm Yard Manure @ 25tons/ha and irrigation with tubewell water. (T-2)	1239	+4	1268	+15	4630	-16.2
Press Mud @ 25 tons/ha and irrigation with tubewell water. (T-3)	1062	-11	1041	-5	4340	-22.2
No Amendments and irrigation with tubewell water. (T-4)	767	-36	953	-13	3800	-31.2

Table 12 Crop yield (kg ha⁻¹) as affected by different treatments at watercourse 1BL.

Treatment	Cotton				Wheat	
	Kharif 2001	Change over control (%)	Kharif 2002	Change over control (%)	Rabi 2001-02	Change over control (%)
No Amendments and irrigations with canal water (control). (T-1)	1060	-	1937	-	5345	-
Farm Yard Manure @ 25tons/ha and irrigation with tubewell water. (T-2)	1074	+1	1625	-16	4815	-9.9
Press Mud @ 25 tons/ha and irrigation with tubewell water. (T-3)	950	-10	1266	-35	4300	-18.8
No Amendments and irrigation with tubewell water. (T-4)	759	-28	1230	-36	3925	-26.6

3.2 Use of Proper Fertilizers Experiment

3.2.1 Changes in Electrical Conductivity (ECe) of Soil

The Electrical Conductivity values for five depths ranging from 0-15 to 90-120 cm during pre Kharif 2001 are given in Table 13. The changes at the end of study will be recorded and compared.

3.2.2 Changes in Sodium Adsorption Ratio of Soil

The soil SAR values for different periods as affected by different treatments are given in Table 14. The SAR values range between 2.3 (normal soil at 60-90 cm depth) to 10.5 (saline soil at 30-60 cm depth) and fall within safe limit of sodicity. The changes in SAR due to various fertilizer treatments will be recorded at the end of study i.e. Rabi 2002-2003.

3.2.3 Tubewell Water Quality

Tubewell water is being used for irrigation in all the treatments. The determination of its quality is important to know the effects on crop response. The quality of tubewell water is changing over time depending on the running time as most of the tubewells are shallow. The tubewell water EC values range from 1800 to 8300 micromhos/cm during different times over the season. Similarly SAR values show variation ranging from 1.7 to 8.0 and needs careful management for its application.

Table 13 Electrical conductivity (dS/m) of soil as affected by different treatments pre-Karif 2001.

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Treatment	Depths (cm)	Watercourse 6R		Watercourse 7L	
		Normal Soil	Saline Soil	Normal Soil	Saline Soil
T-1 = Urea + DAP (Control)	0-15	4.3	4.9	6.6	9.1
	15-30	6.8	5.1	7.5	9.5
	30-60	6.0	6.3	7.4	6.8
	60-90	5.3	5.8	5.3	5.8
	90-120	4.8	4.7	4.1	4.3
T-2 = Ammonium Nitrate +DAP	0-15	3.8	5.8	10.6	9.4
	15-30	5.8	7.8	8.5	8.4
	30-60	6.5	7.4	8.2	6.8
	60-90	6.0	6.6	6.9	5.2
	90-120	4.8	4.5	5.0	5.1
T-3 = Ammonium Sulphate +Nitrophos	0-15	3.9	4.6	8.0	8.0
	15-30	5.9	5.6	7.6	9.4
	30-60	6.1	5.2	7.3	8.6
	60-90	6.0	5.8	6.2	6.6
	90-120	4.0	4.4	6.6	5.6

Table 14 Sar of soil as affected by different treatments pre-Kharif 2001.

Treatment	Depths (cm)	Watercourse 6R		Watercourse 7L	
		Normal Soil	Saline Soil	Normal Soil	Saline Soil
T-1 = Urea + DAP (Control)	0-15	3.7	4.5	4.7	6.9
	15-30	4.9	4.5	8.3	9.4
	30-60	2.9	4.8	9.2	9.0
	60-90	2.8	4.1	6.5	9.6
	90-120	3.6	4.2	6.4	6.0
T-2 = Ammonium Nitrate +DAP	0-15	2.7	4.6	7.1	7.2
	15-30	3.7	4.7	7.0	7.3
	30-60	2.9	4.8	6.1	8.2
	60-90	2.3	3.4	6.9	7.3
	90-120	3.3	3.4	4.9	6.8
T-3 = Ammonium Sulphate +Nitrophos	0-15	4.9	4.9	6.8	5.1
	15-30	3.7	4.7	6.1	7.0
	30-60	3.0	4.9	7.8	10.5
	60-90	3.5	5.1	7.5	8.0
	90-120	3.0	5.2	6.7	7.7

3.2.4 Effect of Treatments on Crop Yields

The yield data for two Cotton crop (Kharif 2001 & 2002) and one Wheat crop for Rabi 2001-02 is given in Table 15 & 16.

The data of Seed Cotton during Kharif 2001 at Watercourse # 6-R normal soil indicate that highest Seed Cotton yield of 1255 kg/ha was obtained from T-3 where Ammonium Sulphate and Nitrophos was applied which is followed by T-2 (Ammonium Nitrate+DAP) and T-3 (Urea+DAP). The same trend is observed on saline soil with maximum yield of Seed Cotton of 1092 kg/ha from T-3 (Ammonium Sulphate+Nitrophos) followed by T-2 and T-1.

The yield data of Seed Cotton given in Table 15 indicates that maximum Seed Cotton yield of 1649 kg/ha was obtained from T-3 on normal soil which is followed by T-2 and T-1. The lowest yield of 1240 kg/ha was obtained from T-1 where Ammonium Nitrate and Urea were applied.

Almost similar trend was observed on saline soil with maximum Seed Cotton yield of 1143 kg/ha followed by 998 kg/ha from T-2 and 935 from T-1.

The highest Wheat grain yield of 5470 kg/ha (Table 16) was obtained during Rabi 2001-02 from Treatment T-3 where Ammonium

DAP (Control) (T-1)	1240	-	4912	-	1120	-	935	-	3760	-	840	-
Ammonium Nitrate +DAP (T-2)	1509	+21.7	5130	+4.4	1388	+23.9	998	+6.7	3883	+3.3	870	+3.6
Ammonium Sulphate + Nitrophos (T-3)	1649	+32.9	5470	+11.3	1505	+34.4	1143	+22.3	4327	+15.1	1092	+30.0

4 CONCLUSIONS

- Awareness has been increased among the farmers regarding use of shallow groundwater as a result of dissemination efforts. They often approach LIM field staff for advice regarding use of tubewell water and fertilizer application.
- Participation of large number of farmers on Farmer's Day shows interest to adopt technologies being disseminated in the area.
- Among the fertilizer type and combinations Ammonium Sulphate+Nitrophos was significantly found better resulting higher Seed Cotton and Wheat grain yield than other combination.
- Poor quality groundwater up to 2000 should not be used for Wheat and Cotton without any amendment (Farm Yard Manure or Press Mud).
- Due to drought conditions, increasing trend of installation of shallow tubewells in the Dhoro Naro Minor Command area, has necessitated further to disseminate the proper use of low quality tubewell water adopting use of amendment such as Gypsum/Press Mud and Farm Yard Manure and use of low pH fertilizer combination (Ammonium Sulphate + Nitrophos) to minimize deleterious effects of its use.
- About equal Seed Cotton and Wheat grain yield were obtained by applying Farm Yard Manure and irrigation with tubewell water when compared with the yield obtained by applying canal irrigation with no Farm Yard Manure.
- Huge amount of irrigation water loss at watercourse level, farm ditches and field level are taking place due to poor maintenance of watercourses, improper land leveling and farm layout.
- Demonstration of studies are the main tools/approaches to motivate the beneficiaries for saving/conserving irrigation water.
- Further research is required to study the effect of amendments and fertilizers using saline water of inferior quality above 2000 ppm on soil properties and crop yields on long term basis.

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