Conjunctive Use of Water: Impact on Soil and Crops

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ABSTRACT:

The economy of Pakistan is closely linked with agriculture and about 75% population of the country is directly or indirectly dependent on agriculture. Half of the GNP also comes from this sector, but unfortunately, this sector is badly confronted with the problems of waterlogging, salinity/sodicity and inadequate availability of good quality irrigation water. The problems are not only affecting agriculture but they are also affecting the country as a whole and its people's socio-economic conditions.

To augment the inadequate water supplies of good quality water the only alternative is groundwater that is generally of poor quality, and as such its use may degrade the scarce land resources. To control the problems of waterlogging and salinity many Salinity Control and Reclamation Projects (SCARPs) were constructed by installing high capacity tubewells. The water quality of these tubewells varies considerably ranging form fresh to hazardous. The water of these tubewells was used in conjunction with canal water and the impact of this conjunctive use on soil, crops etc. was monitored regularly.

The salt affected (saline/sodic) area decreased in almost all the SCARPs due to additional groundwater supply and its conjunctive use with good quality canal water. This decrease in salinity/sodicity varied considerably in different SCARPs depending upon the extent of initial soil salinity/sodicity, volume of additional water provided through tubewell construction and the management practices adopted by the farming community. Waterlogging was also controlled significantly in the SCARPs area. The control in waterlogging and reduction in salt affected area due to SCARPs and conjunctive use of brackish drainage water has also resulted in the increase of crops yield and the improvement in the socio-economic status of the farmer communities. The gross value of production (GVP) of SCARPs has also been enhanced substantially. The results of research studies carried out in the farmers' field depicted the decrease in EC_e and SAR of soil when conjunctive use treatments were compared with pure tubewell water use treatment. The crop yield was not much affected with conjunctive use of water when compared with canal water irrigation treatment only. The conjunctive/cyclic use of brackish water can be adopted for bringing more area under cultivation for meeting the food and fiber requirements of the increasing population of the country.

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INTRODUCTION

Most of the productive area in the country falls in the arid and semi-arid climate. Rainfall is inadequate, uncertain, and scanty and is mostly during monsoon months (June September), which cannot be fully utilized. The success of agriculture is mainly dependant on irrigation through one of the biggest contiguous unlined irrigation systems, which due to excessive seepage resulted in the problem of waterlogging and salinity. During early sixties this problem became so serious that it was considered the top problem for the sustainability of irrigated agriculture in the country. To control this problem the Government of Pakistan launched Salinity Control and Reclamation Projects (SCARPs) by installing big capacity tubewells.

The quantity of good quality water is not sufficient to meet the crop water requirement and to augment this inadequate water supplies of good quality water the only alternative is groundwater. The quality of groundwater varies considerably ranging from fresh to highly saline. This water from the SCARPs tubewells was conjunctively used for irrigation purposes. The impact of tubewell water used in conjunction with canal water was monitored on soil salinity/sodicity, cropping intensities and crops yield. The main objective of this paper is to evaluate the impact of conjunctive use of water on soil properties and crop yield.

WATER RESOURCES

Most of the public tubewells, in fresh and marginal quality zone have been installed on the outlets in order to augment the inadequate water supplies. The water from tubewells mixes with canal water and then is used by the farmers. Some times, the farmers use even poor quality water to meet the crop water requirement. The availability of water from 1997-98 to 2002-3 is presented in Table 1.

Table 1: Water Availability from (1997-1998 to 2002-2003) at farmgate Million Acre Feet (MAF)

Source (K+R)	1997-98	1998-99	1999-2000	2000-2001	2001-2002	2002-2003	Increment
Surface Water	81.95	83.16	84.88	85.62	86.20	86.79	4.84
Groundwater	51.33	51.69	52.05	52.41	52.77	53.14	1.81
Total (S+G Water)	133.28	134.87	136.93	138.03	138.97	139.93	6.65

Reduction storage @ 0.15 MAF per year for Tarbela, Mangla and Chashma combined (2.25 MAF)/ (One MAF = 1.234 BCM) Source: GOP, 1997.

GROUNDWATER QUALITY

In Pakistan a huge quantity of groundwater is available but its quality is highly variable in different parts of the country both vertically and horizontally, from completely fresh to extremely saline. Generally groundwater is fresh in strips along the rivers due to seepage of fresh water but deteriorated in the center of the Doabs.

The data presented in Table 2 depict that 49.4% area is with fresh groundwater, 11.8% is with marginal quality water and 38.8% is with hazardous water. The major part of the fresh and marginal water from the public tubewells is being used in conjunction with canal water.

Table 2: Groundwater Quality in Indus Plain

Province	Area underlain by different groundwater/salinity levels (Mha)			Total Area
	< 1500 mg/l	1500-3000 mg/l	> 3000 mg/l	
Punjab	6.84 (69%)	1.34 (14%)	1.66 (17%)	9.84
Sindh	0.94 (16%)	0.55 (9%)	4.46 (75%)	5.95
NWFP	0.35 (87%)	0.05 (13%)	-	0.40
Balochistan	-	-	0.28 (100%)	0.28
Total Area	8.13	1.94	6.40	16.47
% Area	49.4	11.8	38.8	

Source: Ahmed (1993) (Figures in parenthesis are percentages of the total)

LAND RESOURCES

Total geographical area of Pakistan is 79.61 mha and out of this area 59.28 mha during 1999-2000 falls under total reported area which is a sum of forest area, cultivated waste land, uncultivated area and the area under cultivation but not available (Table 3). The major cultivated and productive areas, in fact, lie in the Indus Basin.

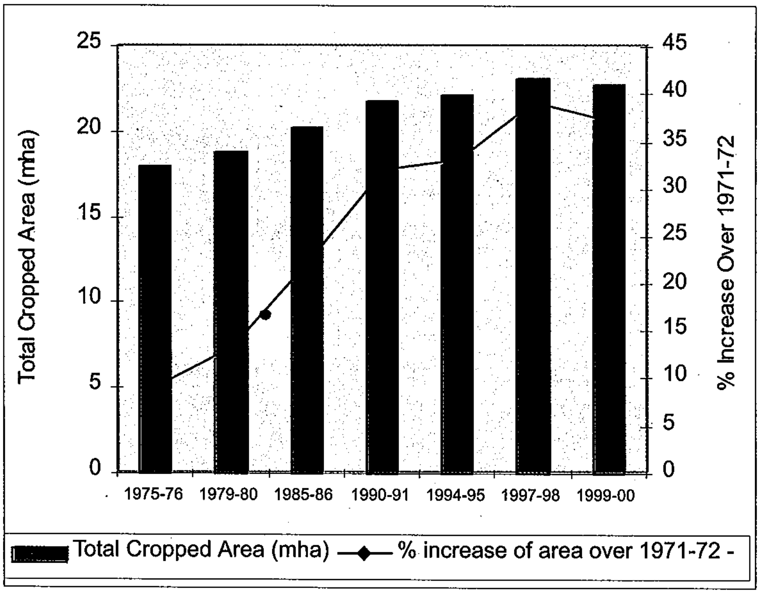
Table 3: Land Use Statistics of Pakistan (area in Million Hectare)

Years	Geographical Area	Total reported Area (4+5+6+7)	Forest Area	Not Available for Cultivation	Cultural Waste	Cultivated Area col. (8+9)	Current Fallow	Net area	Area Sown More than Once	Total Cropped Area (9+10)	% Increase over 1971-72
1971-72	79.61	53.49	2.27	20.43	11.25	19.09	4.75	14.34	2.26	16.60	-
1975-76	79.61	53.92	2.84	20.63	10.62	19.83	4.77	15.06	2.96	18.02	9
1979-80	79.61	55.09	2.84	21.02	11.93	20.30	4.82	15.48	3.32	18.80	13
1985-86	79.61	57.59	3.12	24.52	9.47	20.68	4.91	15.77	4.51	20.28	22
1990-91	79.61	57.61	3.46	24.34	8.85	20.96	4.85	16.11	5.71	21.82	32
1994-95	79.61	58.50	3.60	24.44	8.91	21.55	5.42	16.13	6.01	22.14	33
1997-98	79.61	59.32	3.59	24.55	9.14	22.04	5.35	16.69	6.35	23.04	39
1999-00	79.61	59.28	3.66	24.50	9.13	21.99	5.67	16.32	6.44	22.76	37

Source: GOP, (1980 and 2000)

The total cropped area, either irrigated or barani, in Pakistan constitute 16.60 mha during 1971-72, which has increased up to 22.76 mha during 1999-2000. Similarly, the area under forest has increased from 2.27 mha during 19971-72 to 3.66 mha during 1999-2000. However, the culturable waste has been reduced from 11.25 mha to 9.13 mha during the same period of time. The increase in the total cropped area and percent increase over 1971-72 is presented in Figure-1.

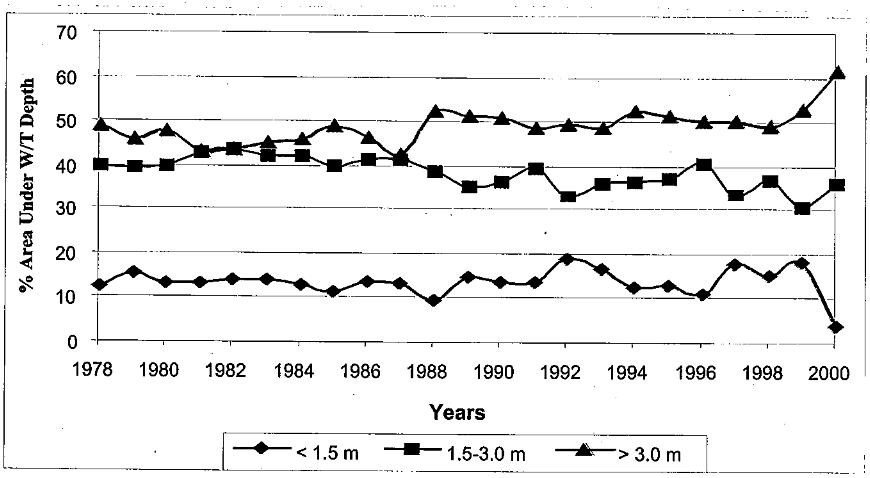
Figure 1: Total Cropped Area and Percent Increase Over 1971-72 of Pakistan.



5. WATERLOGGING PROBLEM

The flat topography, seepage from the canal system, poor water management practices, inadequate provision of drainage and poor operation, and maintenance of the irrigation and drainage systems resulted in severe problem of waterlogging. From 1978 to 2000, the area under less than 1.5 m watertable ranged between 3.3 to 18.3%. Similar variations were also observed in watertable between 1.5 to 3.0 m and greater than 3.0 m area. It is clear from the data present in Figure. 2 that during 2000, the area under less than 1.5 m depth to watertable is only 3.3% which is due to dry spell and less canal water supplies.

Figure 2: Area (%) Under Different Watertable Depths (April – June)



SALINITY/SODICITY PROBLEM

The first salinity survey was conducted during 1953-75 and the second one during 1977-79 in Pakistan. The extent of salinity/sodicity is briefly described as under:-

Surface Salinity

The survey conducted by WAPDA during 1977-1979, brought out the true status of soil salinity in the canal commands. This survey, indicated that in terms of slightly, moderately, and strongly saline soils, about 25 percent of the area (16.72 mha) is affected by surface salinity. The province-wise position of surface salinity in the country is presented in Table 4. Comparison with past survey has indicated that the land affected by surface salinity has decreased from 42% in the early 60s to about 25% in 1977-79. This reduction in surface salinity was primarily due to increased irrigation water supply from surface and groundwater sources, its conjunctive/cyclic use and other measures taken. A contributory factor to this reduction may also be the incidence of exceptional rainfall during 1973-75, a few years before the survey.

Table 4: Province-wise Surface Salinity Status (% of area surveyed/16.72 mha)

Province	Survey Period	Salt Free S1	Slightly Saline S2	Moderately Saline S3	Strongly Saline S4
N.W.F.P.	1977-79 1971-75	78 75	8 10	2 4	2 2
Punjab	1977-79 1953-65	84 72	7 15	4 5	3 6
Sindh	1977-79 1953-54	50 26	19 28	10 17	18 27
Balochistan	1977-79 1953-54	74 69	17 15	5 7	4 9
Pakistan	1977-79 1953-75	72 56	11 20	6 9	8 13

Source: WAPDA (1980)

Profile Salinity/Sodicity (Chemical Status)

The non-saline non-sodic (normal), saline, saline sodic and sodic soils were 55, 6, 27 and 11% according to the survey of 1962-65 but these were 61, 11, 24, 3%, respectively during the later survey of 1977-79 indicating the overall improvement in salt-affected area (Table 5). It is evident from the data that most serious problem of profile salinity/sodicity exists in Sindh province followed by Punjab. A soil salinity survey is being carried out under National Drainage Program, which will show the latest status of soil salinity/sodicity in the country.

Table 5: Province-wise Chemical Status of Soil Profiles (% of Profiles)

Province	Survey Period	No. of Profiles	NSNS*	Saline	Saline Sodic	NSS**
N.W.F.P.	1977-79	1958	79	11	7	2
	1971-75	314	27	50	23	-
Punjab	1977-79	39963	73	7	14	5
	1962-65	23662	55	6	27	11
Sindh	1977-79	20543	38	17	42	2
Balochistan	1977-79	1402	35	26	38	1
Pakistan	1977-79	63866	61	11	24	3
	1962-65	23976	55	6	27	11

** Non-Saline Non-Sodic ** Non-Saline Sodic*
Source: WAPDA (1980)

CONJUNCTIVE USE/SCARPS IMPACT

The impact of Salinity Control and Reclamation Projects and conjunctive use was considerably significant. However, specifically, impact of SCARPs/ conjunctive use on waterlogging, salinity/sodicity and improvement in the socio-economic conditions of the people of some of the SCARPs is discussed as under:

Waterlogging

A network of 5000 observation points has been established in irrigated areas of Pakistan by SMO, WAPDA to monitor the behavior of watertable. The effect of SCARPs/Conjunctive use of water on ground watertable is given in Table 6 indicating reduction in waterlogged area.

Table 6: Impact of SCARPs/Conjunctive Use on Waterlogging

SCARP	Total Area (000 ha.)	Pre-Project			Post-project							
					1987		1988		1989		1998	
		Year	Area	%age	Area	%age	Area	%age	Area	%age	Area	%age
I	493	1961	66.4	13.5	10.5	2.2	2.0	0.4	6.9	1.4	1.2	0.3
II	667	1964	73.2	11.0	47.4	7.1	8.0	1.2	34.0	5.1	32.0	4.8
III	461	1969	189.9	41.0	106.0	23.0	69.0	15.0	119.4	25.9	119.0	25.8
Khairpur	154	1960	45.7	29.7	68.1	44.2	32.8	21.3	52.4	34.0	32.5	21.1
N. Rohri	278	1966	30.6	11.0	10.8	3.9	17.2	6.2	15.6	5.6	27.2	9.8
Fourth Drainage Project, Faisalabad	143	1985	42.9	30.0	-	-	-	-	-	-	32.9	23.0

Source: SMO, (1994) and SMO, (1998 Unpublished).

Soil Salinity/Sodicity

The data presented in Table 7 depict that soil environment has been improved with the reduction of soil salinity at the surface as well as in the profile. The extent of reduction in surface and profile salinity was different but in almost all the SCARPs this surface/profile salinity was considerably decreased.

Table 7: Impact of SCARPs/Conjunctive Use of Water on Surface and Profile Salinity

SCARPs	Surface salinity (% of area)				Profile salinity (% of profiles)			
I	34 (1962-65)	12 (1977-79)	23 (1981-82)	15 (1986-88)	59 (1962-63)	28 (1977-78)	39 (1981-82)	37 (1986-88)
II	44 (1962-65)	22 (1977-79)	12 (1983-85	-	42 (1962-63)	22 (1977-80)	21 (1983-85	-
III	35 (1953-65)	14 (1977-80)	12 (1982-83	-	51 (1962-65)	28 (1977-78)	36 (1982-83)	-
IV	63 (1953-65)	30 (1976-80)	23 (1986-87	-	75 (1962-65)	37 (1977-780	37 (1986-87	-
*Fourth Drainage Project, Faisalabad	44 (1985)	31 (1990)	-	-	50 (1985)	39 (1990)	-	-

*Source: Pakistan ICID Country Report, (1991) and *SMO, (1994 and 1998)*

Socio-economic Impacts

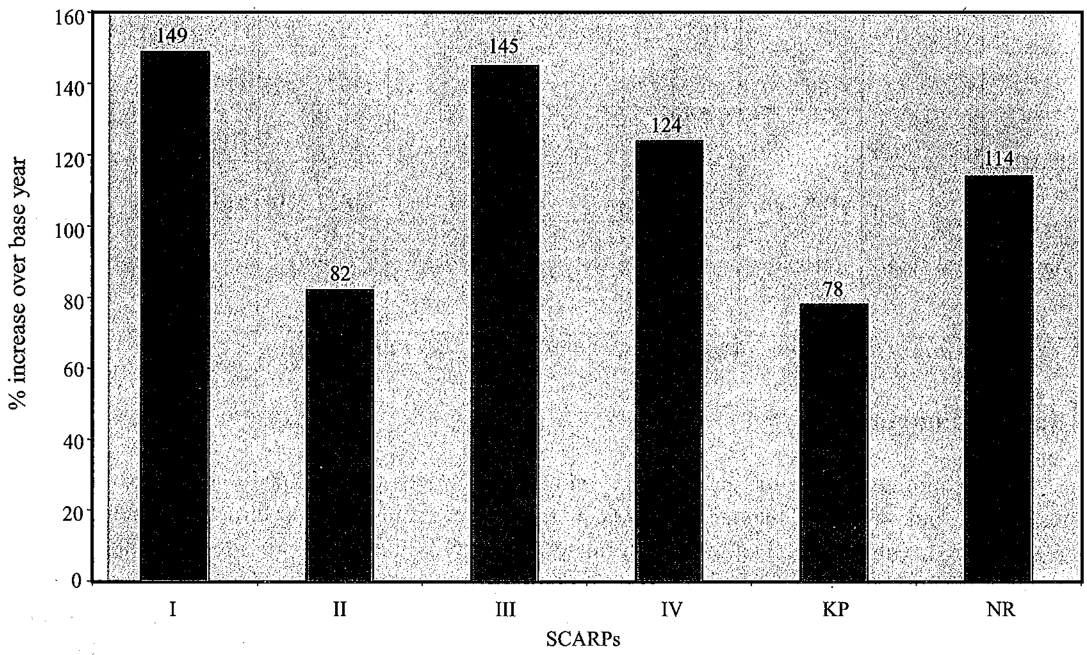
The socio-economic status of the farmers' communities has tremendously improved due to waterlogging and salinity remedial measures. Farmers are getting more return from their lands. Increase in gross value of production (GVP) for some selected SCARPs is provided in Table 8. The data showed that the construction of these projects has enhanced the GVP of the project substantially, and consequently, the socio-economic status of the farming community and allied people has been improved. The graphical presentation of increase in gross value of production is shown in Figure 3.

Table 8: Impact of SCARPs/Conjunctive Use of Water on Gross Value of Production (M.Rs.)

SCARP/Base year	Pre-project	Achieved		% Increase in 1988-89 over Base Year
I (1959-60)	191	452 (1987-88)	476 (1988-89)	149
II (1964)	462	816 (1987-88)	841 (1988-89)	82
III (1969)	181	444 (1987-88)	444 (1988-89)	145
IV (1968-69)	93	225 (1987-88)	208 (1988-89)	124
Khairpur (1966-67)	91	164 (1987-88)	162 (1988-89)	78
North Rohri (1972-73)	319	650 (1987-88)	684 (1988-89)	114

Source: Pakistan National Commission of ICID, (1991)

Figure 3: Impact of SCARPs/Conjunctive Use of Water on Gross Value of Production.



EFFECT OF CONJUNCTIVE USE OF WATER IN COMPARISON WITH OTHER TREATMENTS

The effect of conjunctive use of saline water with canal water in comparison with other treatments on soil properties and crop yield is discussed as under:

Effect on Salinity (EC) and Sodicity (SAR) of soil

The effect of different treatments on the EC_e and SAR of soil is presented below:-

Salinity of Soil (0-15 cm)

Data presented in Table-9 showed that with the exception of the plots irrigated with undiluted tubewell water, the EC_e decreased significantly after a period of three years. The EC_e measurements at the end of the experiment (S7) compared to those taken initially showed reductions of 67, 48, 55, 38 and 47 percent in treatments 1, 2, 3, 4 and 5, respectively. Such reductions were due to the combined leaching effects of scattered rainfall (155 cms) and irrigation applications (369 cms). Where only canal water was used for irrigated, the EC_e was reduced by 67 percent. Contrarily, an increase of 18% was observed where pure tubewell water was applied for irrigation. A considerable reduction was observed where saline water was used in conjunction with canal water or cyclic use was adopted.

Table 9: Effect of Different Treatments on EC_e of 0-15 cm Soil Depth

Treatments	Pre-Wheat 1989-90 S-1	Post Wheat 1989-90 S-2	Post Rice 1990 S-3	Post Wheat 1990-91 S-4	Post Rice 1991 S-5	Post Wheat 1991-92 S-6	Post Rice 1992 S-7	Mean	% decrease/ Increase in S-7 over S-1
T1 Canal Water	5.5	4.3	3.1	3.3	2.3	3.2	1.8	3.4	-67
T2 Alternate irrigation with canal water and T/Well Water	4.2	3.5	3.3	3.4	2.8	3.2	2.2	3.2	-48
T3 Canal and T/Well Water (1:1)	5.5	5,2	3.2	3.8	2.9	2.8	2.5	3.7	-55
T4 First irrigation with canal water and later irrigations with saline water	5.3	4.7	3.2	3.6	3.0	3.5	3.3	3.8	-38
T5 Canal and T/Well Water (1:3)	6.0	6.1	3.2	4.0	3.4	3.5	3.2	4.2	-47
T6 Tubewell Water	3.4	4.2	3.9	4.1	3.6	3.6	4.0	3.8	+18
Mean	4.98 (a)	4.67 (a)	3.32 (b)	3.7 (b)	3.0 (b)	3.3 (b)	2.83 (b)	-	

LSD (samplings) 1% = 0.93 *Mean followed by different letters differ significantly.*
Source: Sidhu et.al. (1996)

In all cases except the tubewells irrigated plot which initially had the lowest soil salinity than the plots under all the other treatments, the most significant reduction in EC_e occurred up to the first post-rice sampling (S3) i-e. within about one year period. The results clearly indicate the importance of leaching by growing a high delta rice crop.

Sodium Adsorption Ratio of Soil (0-15 cm depth)

There was no significant effect of different irrigation treatments on the SAR of soil. However, a reduction of 43, 35, 41, 34, 31 and 6 percent in Treatments 1, 2, 3, 4, 5 and 6 respectively over a three-year period was observed (Table-10). Treatments 1 and 3 showed the best improvement where canal water and canal plus tubewell water in the ratio of 1:1 was applied. However, the initial SAR in Treatment-3 was higher than all others, as expected to show a proportionally larger reduction than Treatments 2, 4, 5 and 6. Application of good quality water reduced soil SAR considerably. The SAR decreased slightly also in Treatment 6 where pure tubewell water was applied. Under the conditions of continuous irrigation with tubewell water, a gradual increase in SAR would be expected; however, the canal water application to the rice crop has provided sufficient leaching to prevent the sodicity build-up and the addition was not sustainable. The SAR was significantly affected during different sampling periods. The SAR was significantly higher in Sampling 1 and 2 as compared to the SAR of other samplings. The minimum SAR of 7.1 was observed in Sampling 5. At the final sampling the SAR again increased which may be due to high watertable (1.25 m) and evaporative conditions under the wheat crop. A sharp reduction in the SAR of soil was observed during rice 1990.

Table 10: Effect of Different Treatments on SAR of 0-15 cm Soil Depth

Treatments	Pre-Wheat 1989-90 S-1	Post Wheat 1989-90 S-2	Post Rice 1990 S-3	Post Wheat 1990-91 S-4	Post Rice 1991 S-5	Post Wheat 1991-92 S-6	Post Rice 1992 S-7	Mean	% decrease/ Increase in S-7 over S-1
T1 Canal Water	14.8	13.8	8.5	9.0	5.1	8.7	8.5	9.77	-43
T2 Alternate irrigation with canal water and T/Well Water	13.9	13.4	9.0	10.2	7.2	9.9	9.0	10.37	-35
T3 Canal and T/Well Water (1:1)	15.7	14.8	9.2	9.9	7.6	9.7	9.3	10.88	-41
T4 First irrigation with canal water and later irrigations with saline water	14.2	13.5	9.2	9.8	8.0	8.7	9.4	10.40	-34
T5 Canal and T/Well Water (1:3)	13.7	13.9	9.6	10.5	7.1	9.9	9.5	10.60	-31
T6 Tubewell Water	11.2	13.2	11.1	12.9	11.7	9.2	10.5	11.40	-6
Mean	13.92 (a)	13.77 (a)	9.43 (b)	10.38 (b)	7.78 (b)	9.35 (b)	9.37 (b)	-	

LSD (samplings) 1% = 0.93 *Mean followed by different letters differ significantly.*
Source: Sidhu et.al. (1996)

EFFECT ON CROP YIELD

Wheat and rice crops were harvested on the whole plot basis, threshed and weighed separately to assess crop production, and the treatment effects are discussed as below:

Wheat Grains Yield

Wheat grain yield was affected significantly by various irrigation treatments (Table-11). Maximum average wheat grain yield of 3815 kg ha^{-1} was recorded in Treatment 1 where all irrigations were applied with canal water, which was significantly higher than the yield obtained in Treatments 6. The difference among the first four treatments was non significant. On an average, the minimum yield of 3139 kg ha^{-1} was recorded in Treatment 6 where tubewell water was used. Low grain yield in Treatment 6 where tubewell water was applied is attributed to the salt additions through saline irrigations (Figure-4). Wheat grain yield differed significantly season-wise. It was the highest during 1989-90 and then reduced during subsequent years. Reduction may be due to seasonal variation, insufficient NPK or plant water stress between irrigations at critical physiological stages of growth.

There was 13% reduction in wheat grain yield during 1990-91 and 21% reduction during 1991-92 over 1989-90.

Table 11 Effects of Different Treatments on Wheat Grain Yield (kg ha^{-1})

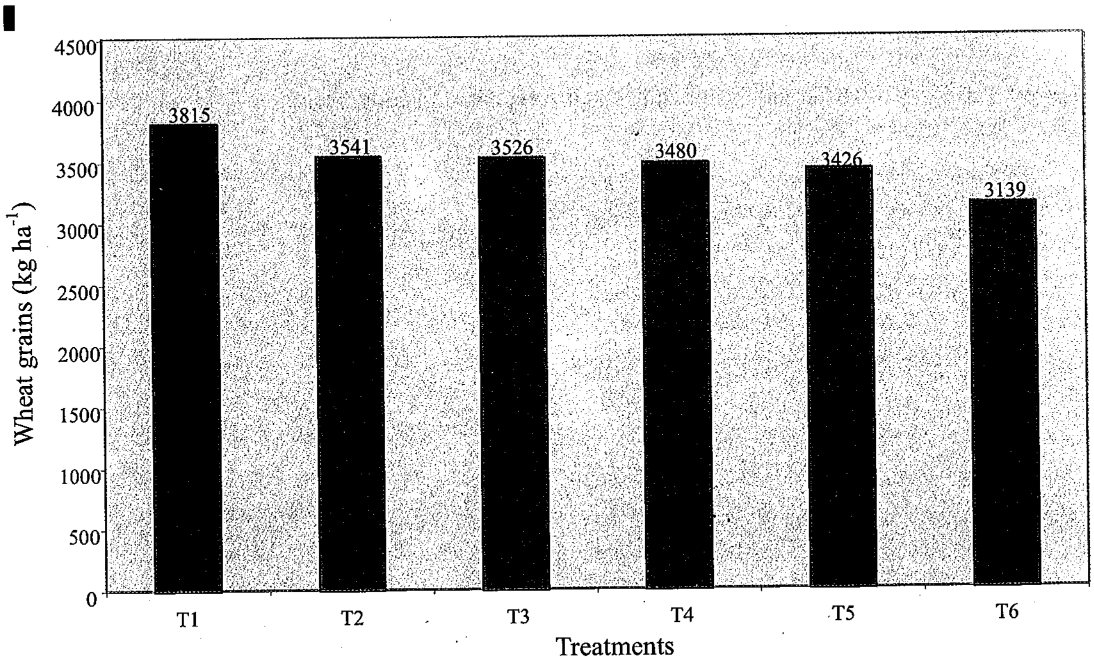
Treatments	1989-90	1990-91	1991-92	Mean	% decrease over T-1
T1 Canal Water	4142	3694	3610	3815 (a)	-
T2 Alternate irrigation with Canal and Tubewell Water	4036	3422	3163	3541 (ab)	-7
T3 Canal and Tubewell Water (1:1)	3993	3438	3146	3526 (ab)	-8
T4 First irrigation with canal water and later irrigations with saline water	3993	3553	3094	3480 (abc).	-9
T5 Canal and T/Well water (1:3)	3773	3388	3116	3426 (bc)	-10
T6	3741	3207	2470	3139 (c)	-18
Mean	3946 (a)	3417 (b)	3100 (c)	-	-
% Decrease over 1989-90		-13	-21	-	-

LSD (Treatments) 5% = 367.80 *LSD (Years) 5%= 260.08*

Means followed by different letters differ significantly.

Source: Sidhu et.al. (1996)

Figure 4: Effects of Different Treatments, on an Average, on Wheat Grains Yield.



Paddy Yield

The paddy yield was also affected significantly with different treatments and the yield obtained in Treatments 1 and 2 was significantly higher as compared to the yield of Treatments 5 and 6, but based on the percent decrease there was not much reduction in paddy yield (Table 12). On an average, the highest yield of 1949 kg ha^{-1} was found in Treatments 2, where alternate irrigations with fresh and saline water were applied (Figure 5) but it did not differ significantly from Treatment 1 where canal water was applied.

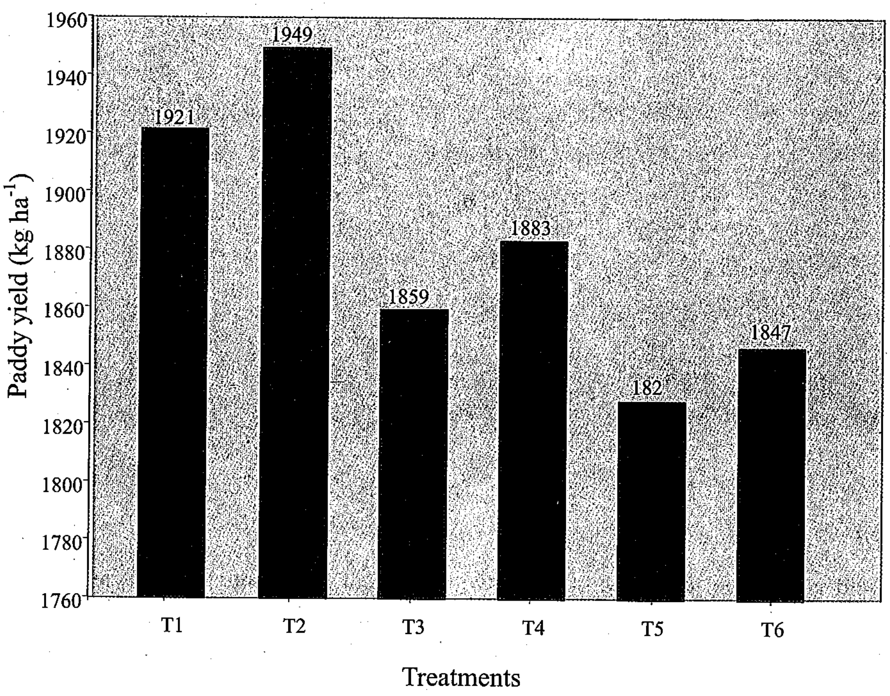
Paddy yield also differed significantly between seasons. In the first season the yield was higher compared to the following two other Kharif seasons. The data further revealed that there was 35% decrease in paddy yield during 1991 over 1990 and 23 % during 1992. This was possibly due to timely non-availability of adequate canal irrigation water and salt accumulation in the soil.

Table 12: Effects of Different Treatments on Paddy Yield (kg ha^{-1})

Treatments	1989-90	1990-91	1991-92	Mean	% decrease over T-1
T1 Canal Water	2349	1548	1848	1921 (ab)	-
T2 Alternate irrigation with canal and Tubewell Water	2447	1553	1848	1949 (a)	+1
T3 Canal and Tube/well Water (1:1)	2287	1492	1799	1859 (bc)	-3
T4 First irrigation with canal water and later irrigations with saline water	2312	1512	1826	1883 (abc)	-2
T5 Canal and T/Well water (1:3)	2291	1466	1727	1828 (c)	-5
T6	2312	1523	1705	1847 (c)	-4
Mean	2333 (a)	1516(b)	1795 (b)	-	-
% Reduction over 1989-90		-35	-23	-	-

LSD (Treatments) 5% = 65.50 *LSD (Years) 1%= 65.88*
Means followed by different letters differ significantly.
Source: Sidhu et.al. (1996)

Figure.5: Effects of Different Treatments, on an Average, on Paddy Yield.



CONCLUSIONS

- Conjunctive use of water in SCARPs resulted in the decrease of soil salinity/sodicity.
- Installation of public and private tubewells helped in controlling waterlogging.
- Gross value of production significantly increased with conjunctive use of water/SCARPs.
- Conjunctive use of canal and T/Well water in 1:1 and even 1:3 ratios reduced the soil salinity/sodicity of upper 15 cm soil considerably.
- Slight decrease in wheat grains and paddy yield was observed with the conjunctive use of canal and brackish tubewell water compared with canal water.

RECOMMENDATIONS

- If need prevails for use of brackish water it should be applied in conjunction with good quality water or its cyclic use be adopted.
- High sodic water should only be applied after amending with some proper treatment/ amendment.
- Available technology, in simple language, should be transferred to end users especially the farmers.
- Experiments should be conducted under different soil and climatic conditions to have technology for site-specific conditions in the country.

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