

Effect of Marginal Quality Groundwater on Yield of Cotton Crop and Soil Salinity Status

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Abstract—In this paper, effect of marginal quality groundwater on yield of cotton crop and soil salinity was studied. In this connection, three irrigation treatments each with four replications were applied. These treatments were i) use of canal water (T_1), ii) use of marginal quality groundwater from tubewell (T_2), and iii) conjunctive use by mixing with the ratio of 1:1 of canal water and marginal quality tubewell water (T_3).

Water was applied to the crop cultivated in Kharif season 2011; its quantity has been measured using cut-throat flume. Total 11 watering each of 50 mm depth have been applied from 20th April to 20th July, 2011. Further, irrigations were stopped due to monsoon rainfall up to crop harvesting.

Maximum crop yield (seed cotton) was observed under T_1 which was 1,517 kg/ha followed by T_3 (mixed canal and tubewell water) having 1009 kg/ha and T_2 i.e. marginal quality groundwater having 709 kg/ha. This concludes that crop yield in T_2 and T_3 in comparison to T_1 was reduced by about 53 and 30% respectively.

It has been observed that yield of cotton crop is below potential limit for three treatments due to unexpected rainfall at the time of full flowering season; thus the yield was adversely affected.

However, salt deposition in soil profiles was not observed that is due to leaching effect of heavy rainfall occurred during monsoon season.

Keywords—Conjunctive Use, Cotton Crop, Groundwater, Soil Salinity Status, Water Use Efficiency (WUE).

I. INTRODUCTION

THE total water in Indus Basin Irrigation System (IBIS) is about 143 million acre-foot (MAF). Water with surface and groundwater availability per annum at watercourse head is about 116 and 27 MAF respectively [1]. On the contrary, the total water requirement based on population predicted in coming year 2025 would be about 216 MAF. Literature [2], [3] show that 50-60 percent of total surface water is lost because of various reasons i.e. i) seepage from unlined canals and the watercourses, ii) improper maintenance of irrigation system, iii) mismanagement of irrigation water, iv) unlevelled fields and v) practicing of old traditional irrigation methods.

Meanwhile, the increasing population have resulted an increase of activities in agriculture to meet food and fiber; which has pushed more pressure on water demand.

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Saline groundwater or drainage effluent is utilized for raising only some crops. Nevertheless, its successfulness depends upon the level of water quality, soil type and the crop. However, there are some drawbacks such as accumulation of salts in the root zone [4]. In spite of that, many countries have used saline/marginal quality groundwater for growing various crops [5]. Marginal quality of ground water is often used in Middle East countries and India [6].

Keeping in view the above facts, this research study has been carried out to determine effects of marginal quality groundwater in conjunction with surface water on cotton yield and to assess soil salinity status under different irrigation treatments.

II. THE STUDY AREA

The study has been carried out in the Drainage and Reclamation Institute of Pakistan (DRIP), Tandojam, Pakistan, which is equipped with all research facilities at an area of about 25 acres. There is an agro-climatic station and Soil-Water laboratory. There is also availability of canal water and a tubewell having marginal quality of groundwater for irrigation purpose. The study was conducted in Kharif season (April-October 2011).

III. MATERIAL AND METHODS

An agricultural land of 0.24 acre (981 m²) was ploughed and leveled thoroughly. It was divided in 12 equal plots each has an area of 81.75 m². In each plot, bed and furrows of 45 and 75cm wide respectively were prepared for sowing cotton crop. Three irrigation treatments were set as follows:

- i) Treatment # 1: Irrigation with canal water only (T_1),
- ii) Treatment # 2: Irrigation through marginal quality tubewell water only (T_2) and,
- iii) Treatment # 3: Irrigation by conjunctive use of canal and tubewell water by mixing with 1:1 ratio (T_3).

All three treatments with four replications were distributed randomly in all 12 field plots in order to avoid soil fertility error. The layout plan is shown in Fig. 1.

BT 113 variety of cotton seeds was dibble in middle of ridges/beds to maintain 30cm plant-to-plant distance. Water delivered to each plot was measured by a cut-throat flume (having throat size of 4 inches) refer. [7]. Water applied has been noted for each plot (i.e. about 50 mm depth). As per Agricultural Research Institute, Tandojam, Pakistan [8], all irrigation practices were utilized.

In order to know water quality, samples of tubewell and canal water were collected each time before irrigation to cotton crop. In all, six groundwater and six canal water

samples were collected and analyzed for EC_w, pH, SAR and RSC parameters.

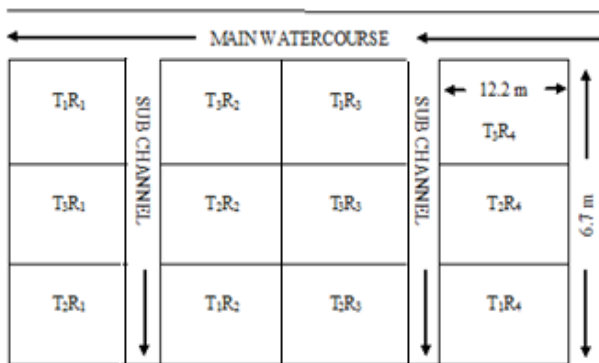


Fig. 1 Layout plan showing replication wise distribution of treatments and irrigation methods

Similarly, to know the soil texture of the experimental area, five composite soil samples at depths 0-15cm, 15-30cm, 30-60cm, 60-90cm, and 90-120cm were drawn and analyzed for soil texture determination. In addition to this, to observe the change in soil salinity /sodicity, composite soil samples at depths 0-15cm, 15-30cm, 30-60cm, 60-90cm and 90-120cm were drawn before crop sowing and after harvest from experimental plots under each treatment/replication. These soil samples were analyzed for E_c, pH and SAR parameters.

IV. RESULTS AND DISCUSSIONS

A. Total Water Applied

Total water includes irrigation water (i.e. fresh surface water from canal and marginal quality water from tubewell) and the effective rainfall. First irrigation was given on 20th April, 2011, whereas the last irrigation was applied on 20th July, 2011. Total watering were 11, each of 5cm depth; hence total volume of water per plot was 4.09m³. After 20th July, 2011 no irrigation was given as rainfall occurred due to monsoon up to crop harvested [9]. The total irrigation water used under each treatment along with effective rainfall is presented in Table I.

Table I indicates that total irrigation water used under each treatment was 5503 m³/ha as each treatment got same quantity of water. Similarly, the effective rainfall computed [10] for each treatment was 422 m³/ha. Thus, the total water (irrigation water + effective rainfall) used for each treatment became 5925 m³/ha.

B. Crop Yield and Water Use Efficiency

The yield (seed) of the cotton crop was measured in kg/ha and water use efficiency was computed as follows:

$$\text{WUE (Kg/m}^3\text{)} = \text{crop yield (kg/ha)} / \text{water used (m}^3\text{/ha)}$$

Total water used, crop yield and water use efficiency under T₁, T₂ and T₃ are presented in Table II.

TABLE I
TOTAL WATER APPLIES TO THE CROP PLUS EFFECTIVE RAINFALL UNDER VARIOUS TREATMENTS

Treatments	Water used (m ³ /ha)	Effective rainfall (m ³ /ha)	Total water (m ³ /ha)
T ₁	5503	422	5925
T ₂	5503	422	5925
T ₃	5503	422	5925

TABLE II
WATER USED, CROP YIELD AND WUE OF COTTON UNDER VARIOUS TREATMENTS

Treatments	Total Water Used (m ³ /ha)	Total crop yield (kg/ha)	WUE (kg/m ³)
T ₁	5925.0	1516.8	0.26
T ₂	5925.0	709.5	0.12
T ₃	5925.0	1009.2	0.17

Table II reveals that under T₁, T₂ and T₃, the cotton yield obtained was 1516.8, 709.5 and 1009.2 kg/ha respectively. Highest yield was obtained under T₁ (canal water) followed by T₃ (canal + groundwater) and T₂ (irrigation with groundwater alone). This indicated that marginal quality groundwater (EC_w between 1.5 to 3.0 dS/m, pH < 8.2 and SAR < 10.0) affected the cotton yield to a considerable level as compared to canal water alone and mixed canal and groundwater. The yield reduced by 53.2% and 29.7% under T₂ and T₃ respectively as compared to T₁. It has been observed that cotton yield obtained under this study even irrigation with good quality water i.e. canal water, was beyond potential yield i.e. 4000 to 5000 kg/ha.

Table II also indicates that like crop yield, highest water use efficiency of cotton was observed under T₁ i.e. 0.26 kg/m³ followed by T₃ and T₂ i.e. 0.17 and 0.12 kg/m³ respectively. Thus, water use efficiency under T₁ and T₃ was higher as about 53.8% and 29.4% as compared to T₂. The results are more or less in agreement to those found by Ahmed [11] and Patra et al. [12].

C. Irrigation Water Quality

Quality of irrigation water is a key parameter in crop production; good quality water increases crop yield whereas use of saline/marginal quality water not only decreases crop production but also increases soil salinity.

In order to know the quality of canal and groundwater used for irrigation of cotton crop, samples were collected and analyzed in the laboratory. The analytical results are presented in Table III.

Table III shows that all six canal water samples of good quality having electrical conductivity (EC) value are less than 1.5dS/m and SAR less than 4.0. On the contrary the tubewell water, having EC value varies from 1.7 to 1.8 dS/m, was of marginal quality i.e. saline non-sodic.

TABLE III
QUALITY OF USED IRRIGATION WATER

S. No.	Collection Date	Source of water	EC _w (dS/m)	pH	SAR	RSC	Water Quality
1	21.04.2011	Canal	0.5	7.6	3.8	Nil	Good
2	21.04.2011	Tubewell	1.8	7.8	4.1	Nil	Marginal
3	30.04.2011	Canal	0.5	7.4	3.1	Nil	Good
4	30.04.2011	Tubewell	1.8	8.0	4.2	Nil	Marginal
5	09.05.2011	Canal	0.4	7.4	3.7	Nil	Good
6	09.05.2011	Tubewell	1.7	7.8	4.2	Nil	Marginal
7	13.05.2011	Canal	0.5	7.3	3.6	Nil	Good
8	13.05.2011	Tubewell	1.7	7.8	4.5	Nil	Marginal
9	26.05.2011	Canal	0.5	7.4	3.6	Nil	Good
10	26.05.2011	Tubewell	1.7	7.8	4.3	Nil	Marginal
11	25.06.2011	Canal	0.4	7.4	3.7	Nil	Good
12	25.06.2011	Tubewell	1.7	7.8	4.6	Nil	Marginal

D. Soil Texture

Soil samples were also collected to determine percentage of sand, silt and clay contents in the soil. In this connection, analysis of the soil samples was made (see Table IV). Analysis shows that soil texture is vary from loam to silt loam i.e. well-drained and suitable for all types of crop cultivation.

TABLE IV
ANALYSIS OF SOIL SAMPLES FOR SOIL TEXTURE CLASS

S. No.	Sampling depth (cm)	Sand (%)	Silt (%)	Clay (%)	Textural Class
1	0 – 15	38.8	37.6	23.6	Loam
2	15 – 30	28.8	59.6	11.6	Silt loam
3	30 – 60	32.8	45.6	21.6	Loam
4	60 – 90	26.8	55.6	17.6	Silt loam
5	90 – 120	26.8	61.6	11.6	Silt loam

E. Soil Salinity-Sodicity Status

It is necessary to know the soil salinity-sodicity status before sowing and after harvesting of the crop, the soil samples under each treatment were taken and analyzed in connection with pH, ECe and SAR. The results are shown in Figures 2 to 10.

1. Electrical Conductivity (ECe)

The variation of ECe of various soil samples before crop sowing was observed for all treatment fields (see Figs. 2 to 4). These figures indicates that soils were non-saline (ECe less than 4 dS/m), the ECe values were decreasing after harvesting at almost all sampling depths.

The reduction of ECe values after harvesting is documented due to monsoon rainfall happened that has leached down all the salts below root zone depth.

2. pH Value

The pH values of soil samples under treatments T₁, T₂ and T₃ are shown in Figs. 5-7. Each figure has two curves i.e. before and after harvest of crop i.e. for all five different depths; pH values are indicating harmless in all respect. However, pH values are undulating with respect to sampling depth and time.

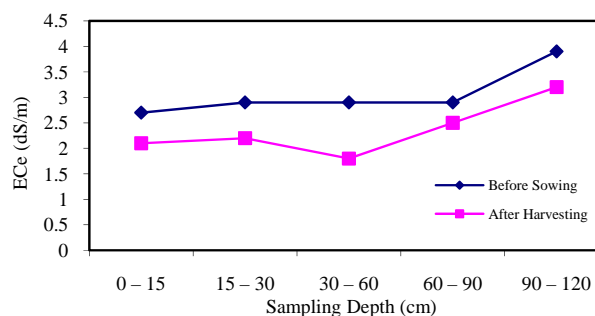


Fig. 2 Average ECe for Treatment T₁

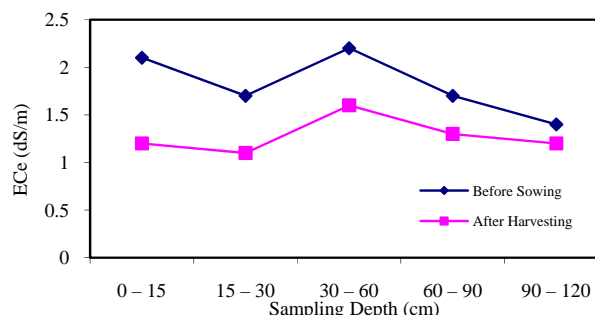


Fig. 3 Average ECe for Treatment T₂

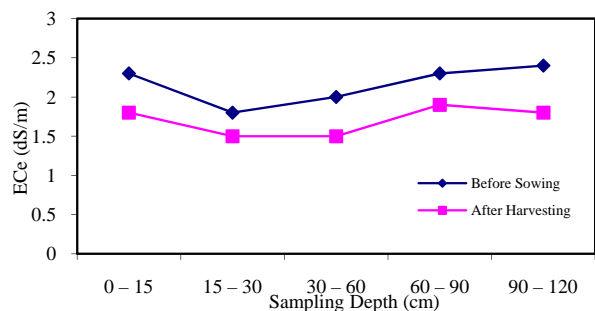


Fig. 4 Average ECe for Treatment T₃

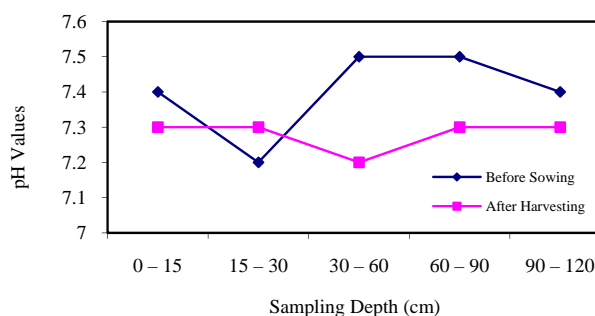


Fig. 5 Average pH values for Treatment T₁

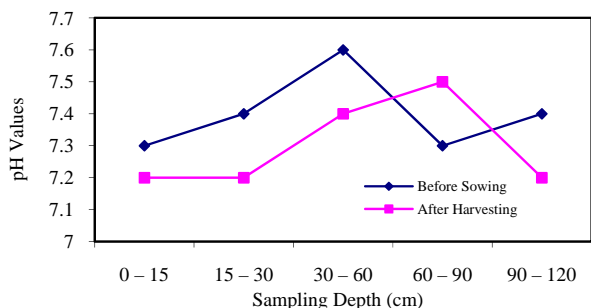


Fig. 6 Average pH values for Treatment T₂

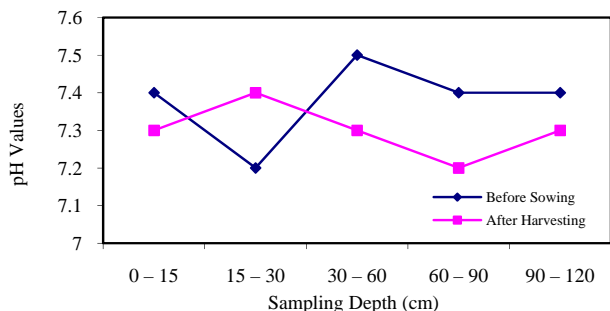


Fig. 7 Average pH value for Treatment T₃

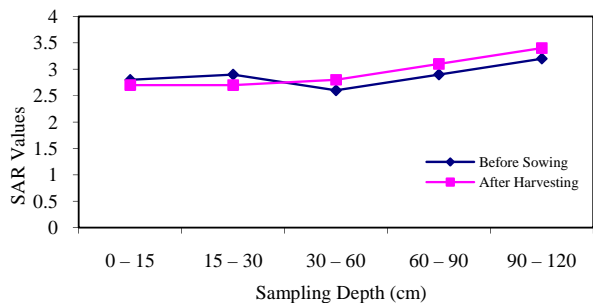


Fig. 8 Average SAR values for Treatment T₁

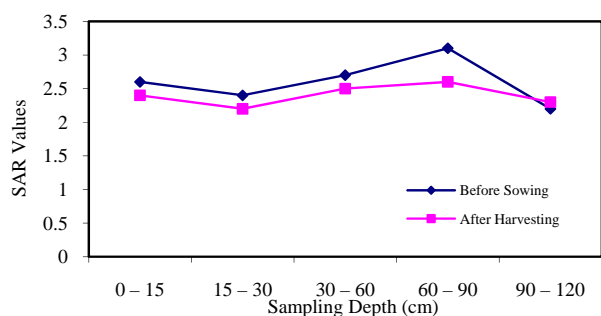


Fig. 9 Average SAR values for Treatment T₂

3. SAR Value

Likewise above, the graphs of SAR values are drawn for all treatments (T₁, T₂ and T₃) in Figs. 8-10. These graphs show that values of SAR are varying from 2.2 to 3.2 irrespective of before and after sowing. Hence, it is concluded that there no

sodicity in the soil as SAR values are less than 7.0. The details of discussions are described in [9].

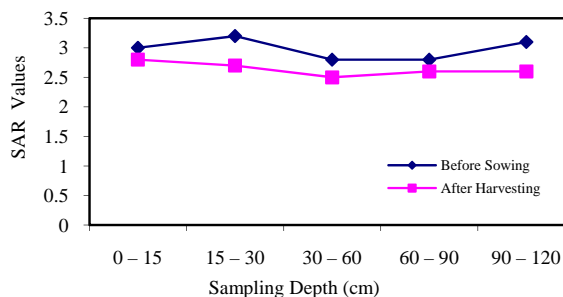


Fig. 10 Average SAR values for Treatment T₃

Consequently, the laboratory results demonstrate that the soil is non-saline and non-sodic even after crop harvesting for all treatments; that is due to remarkable rainfall took place during harvesting period of the crop.

V. CONCLUSION

Form this study, the following conclusions are drawn:

The laboratory analysis results of irrigation water samples i.e. canal water and tubewell / ground water indicated that canal water was non-saline and non-sodic which revealed its good quality. The tubewell water was non-sodic but moderately saline; thus exhibited its quality as marginal.

Under T₁ (irrigation with canal water alone), T₂ (irrigation with marginal groundwater alone) and T₃ (irrigation with canal and tubewell water in 1:1 ratio), cotton yields of 1516.8, 709.5 and 1009.2 kg/ha respectively were obtained. Thus, a significant reduction in yield for T₂ and T₃ was noted as 53.2% and 29.7% respectively over T₁. Similarly, WUE under T₁, T₂ and T₃ was observed as 0.26, 0.12 and 0.17 kg/m³. The low crop yield and WUE in all three treatments were beyond potential which endorsed due to unusual rainfall (503.88mm) occurred during full flowering period.

The texture of the soil was determined as silt loam up to a sampling depth of 120cm indicating that it was favorable for cotton crop cultivation having good drainability.

The analysis results of soil samples collected for salinity appraisal, indicated that no any remarkable change in salinity /sodicity parameters i.e. ECe, pH and SAR were observed under all the three treatments after harvest of crop. This might be due to the fact that heavy rainfall occurred during crop growing period which did not allow salts to be deposited in the soil profile because of leaching effects.

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