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Influence of Watertable Depth on Soil Sodicity and Salinity

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***Abstract*—**In order to monitor the water table depth on soil profile salinity buildup, a field study was carried out during 2006-07. Wheat (Rabi) and Sorghum (Kharif) fodder were sown in with three treatments. The results showed that watertable depth lowered from 1.15m to 2.89 m depth at the end of experiment. With lower of watertable depth, pH, ECe and SAR decreased under crops both without and with gypsum and increased in fallowing. Soil moisture depletion was directly proportional to lowering of watertable. With the application of irrigation water (58cm) pH, ECe and SAR were reduced in cropped plots, reduction was higher in gypsum applied plots than non-gypsum plots. In case of fallowing, there was increase in pH, EC, while slight reduction occurred in SAR values. However, soil salinity showed an increasing upward trend under fallowing and its value in 0-30 cm soil layer was the highest amongst the treatments.

***Keywords*—**Aquifer, Soil Salinity, Soil sodicity, Water table

I. Introduction

PAKISTAN is an agricultural country and it is confronted with the problem of waterlogging and salinity. Conversely, the present canal supplies are not sufficient to fulfill the required crop water dements. Population is increasing at an alarming rate. The increased food and fiber need can only be fulfilled by increasing cropped area and economic crop yields [1].

Salinity is an excess of soluble salts in the soil. Sodium, calcium, and magnesium most commonly form salts with chloride, sulfate, and bicarbonate. Sodicity is an excess of sodium; in sodic soils, sodium represents more than about 10% of all the cations Salinity -and sodicity are important indicators because high salinity inhibits crop growth, while high sodicity leads to loss of soil structure [2]. Sodicity may be the more obscure problem, but it is a more widespread form of land degradation that affects major portion of soils, causing poor water infiltration, surface crusting, erosion and waterlogging. In saline soils, sodium has a partner in crime, chlorine, with which it forms a salt. The presence of salt in the soil reduces the availability of water to plants and at high enough concentrations can kill them. In sodic soils, much of the chlorine has been washed away, leaving behind sodium ions (sodium atoms with a positive charge) attached to tiny clay particles in the soil. As a result, these clay particles lose their tendency to stick together when wet, leading to unstable soils which may erode or become impermeable to both water and roots [3].

Ground water depth and its quality play an important role in salinization/ alkalization of soils in arid and semi-arid areas; hence watertable depth, its salt concentration and composition are considered key elements in the appraisal, monitoring and amelioration of the salt-affected lands. Soil salinity occurs when the salt in the soil profile is brought to the surface by rising watertables [4]. Groundwater is, as the name implies, water in the ground. Usually, somewhere below the surface of the soil, the soil is saturated with water. The top surface of the groundwater layer is called the watertable. Water that drains through the soil profile and reaches the watertable is known as recharge; water leaving the groundwater, perhaps through uptake by tree roots, or when it flows into a river system is called discharge [5].Sindh has serious problems of water logging and salinity due to the nominal gradient, accretion of riverbeds, inadequate salt exit and traditional watering of crops. The problems of water logging and salinity pose a major threat to sustainability of irrigated agriculture on about 30 percent of irrigated lands in Sindh. This situation is aggravated by the low efficiency of the irrigation system [6]. Extraction of deep groundwater further aggravates the issue. In 1999, the waterlogged area, with water table depth 0 to 1.6 metres, was 2.2 million ha, which however drastically reduced to 285,000 ha due to drought conditions in 1999-2000, but would be likely to increase again once the canal supplies return to normal [7].The total land area of Sindh province is 14.09 mha, out of this 5.60 mha are cultivable, about 1.49 mha is culturable wastes and 1.03 mha is under forestry, 5.96 mha is not available for cultivation. Of the total cultivated areas of 5.60 mha, 2.86 mha are current fallow, and the net area sown is 2.74 mha. Hence, the total cropped area is 3.72 mha and area sown more than once is 0.98 mha. Out of the salt free (cultivated or cropped areas), which are 3.72 mha, about 2.32 mha are salt-affected. This includes 1.342 mha of highly saline, 0.673 mha of permeable saline-sodic, 0.277 mha of impermeable saline-sodic and 0.028 mha of sodic soils [8].

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The menace of salinity is towards increasing end. The experts have estimated that the fertile lands of Pakistan are becoming saline at the rate of 40,000 hectares annually. This shows that 109 hectares of our land is converting into saline daily. This situation is very alarming and particularly in Sindh province, because lands are becoming saline more in Sindh than the other provinces. About 50 percent area of Sindh is affected by water logging and salinity caused by defective practices such as flood irrigation, improper irrigation management and inadequate drainage facilities. Moreover, salinity is generally responsible for about 25 percent reduction in crop production. The impact is closer to 40 to 60 percent in Sindh where the problem is more pronounced [9]. According to the recent surveys [10], out of the total cultivated area of Sindh, 6% is <1 m depth, 24% 1-2 m depth, 27% 2-3 m depth and 40% >3 m depth. Thus, about 57% of the total cultivated area of Sindh is <3 m depth, which obviously is the major cause of increasing soil salinity and sodicity. Feeling the gravity of the situation, the study has been planned to determine the effect of water table depth on soil salinity and soil sodicity.

II. MATERIALS AND METHODS

A. Experimental Site:

The experiments were carried out in village Khatiyan, near Tandojam, district Hyderabad. The watertable depth was measured below natural surface at the start of the study.

B. Observation Well and Piezometer Installation

A well approximately 300 m away from the experimental field will be selected for watertable monitoring during the experiment. An observation well was selected and Piezometer was installed in the field to record the watertable depth during the experimental period. The bottom of the piezometer was closed with a wooden cork to prevent disturbances in water level. After that its development was made with the help of a plunger. The elevation of observation well was 1.5 m higher than that of the piezometer plot. Watertable depth was recorded at about one month’s interval. Wheat crop was sown in the 1st week of November 2006 with three treatments: T1=Fallow (unsown), T2=Crop without gypsum and T3=Crop with gypsum application. Gypsum was applied at the rate of 100% GR at sowing time. Wheat crop was harvested in the 1st week of April, 2007. Kharif fodder (sorghum) was sown in the last week of May, 2007 with the same treatments. Soil samplings were made upto 150 cm depth with 30 cm interval at different watertable depths.

C. Water sampling

Water samples from the piezometer and observation well will be collected at about one month interval, with the help of a bottle attached to the lower end of the measuring tape. Temperature of both the water will be recorded at the spot and water samples will be preserved in small plastic bottles for analysis. Temperature of the air will also be recorded at spot. The observations were recorded on Soil depth (cm), Textural class, Saturation percentage, pH, EC, Soluble cations, Soluble anions, CaCO3 equivalent % and SAR.

D. Irrigation Application

A measured quantity of irrigation water was applied to wheat and fodder crops as per the following schedule:

TABLE I
IRRIGATION SCHEDULE

Date of irrigation application	Crop to which water was applied	Description	Quantum of water applied (cm)
01.11.2006	Wheat	Pre-sowing	10.61
28.12. 2006	Wheat	1st irrigation	8.94
08.02. 2007	Wheat	2nd irrigation	8.78
15.03. 2007	Wheat	3rd irrigation	8.00
03.05. 2007	Kharif fodder	Pre-sowing	8.40
24.05. 2007	Kharif fodder	1st irrigation	8.12
08.06. 2007	Kharif fodder	2nd irrigation	7.82
06.07. 2007	Kharif fodder	3rd irrigation	7.36

TABLE II
SCHEDULE OF SOIL SAMPLING

Depth to water table (m)	Date of soil sampling	Remarks
1.15	31.10. 2006	1st sampling
1.40	07.03. 2007	2nd sampling
1.89	10.04. 2007	3rd sampling
2.28	13.06. 2007	4th sampling
2.53	01.08. 2007	5th sampling
2.89	004.10. 2007	6th sampling

E. Soil Sampling

Soil samplings were made to monitor salinity changes in the soil profile depending upon the field condition to permit sampling and other facilities concerned. Soil samples were collected with 30 cm interval from soil surface upto 150 cm depth with different waterable depth from cropped as well as fallow plots. These samples were dried, sieved and then analysed in the laboratory for further analysis.

III. RESULTS AND DISCUSSION

A. Influence of waterable depth on ECe of the soil without crop cover (fallow)

Effect of waterable dept on electricity conductivity of fallow plot is presented in Table.III.The data show that with increase in waterable dept form “1.15 - 2.28” m the ECe of 0-30 cm soil layer decreased from “12.80 - 7.76” dsm-1 and at the end of the experiment when waterable reached 2.89 m, the ECe again increased to 14.75 dsm-1. The ECe of 30-60 cm, “90-120” cm and “120-150” cm soil layer remained unchanged. However, ECe of 60-90 cm soil layer decreased from “5.01 - 2.47”dsm-1 at the time of 2.28 m waterable depth but was not affected considerably at other water depths.

ECe decreased from "12.80-7.76"dsm-1 at 2.28 waterable depth during the period i.e. 31.10.1986 to 13.6.1987 with 289.83 cm of rainfall and 10.6 cm pre-sowing water application. After that ECe increased from 7.67 dsm-1 to 14.75 at 2.89 m waterable depth due to higher evaporation, high temperature, low rainfall (19.1 cm) and humidity during 13.6.87 to 5.10.1987. High evaporation enhanced capillary action to cause increase in ECe of the upper-most soil layer. The results are in agreement with the work [1]. The decrease in ECe of 60-90 cm soil layer was due to low ECe of ground water [11] caused by 28.83 cm of rainfall and 10.6 cm pre-sowing water application.

TABLE III
INFLUENCE OF WATERABLE DEPTH ON ECE OF THE SOIL WITHOUT CROP COVER (FALLOW)

Date	Waterable depth (m)	Soil depth (cm)				
		0-30	30-60	60-90	90-120	120-150
28.10.2006	1.15	12.80	5.66	5.01	3.11	2.61
7.3.2007	1.40	9.89	7.95	7.69	4.76	3.63
08.4.2007	1.83	8.45	4.75	5.69	2.64	2.58
11.6.2007	2.28	4.67	6.83	2.47	2.39	2.73
01.8.2007	2.53	9.25	5.46	3.80	2.95	2.99
04.10.2007	2.89	14.75	5.42	3.81	3.87	2.86

B. Influence of waterable depth on ECe of the soil under crop cover

The effect of waterable depth on the electrical conductivity of the soil saturation extract (ECe) is presented in Table.IV. The data show that by lowering waterable from 1.15 m to 2.53 m, ECe of all the soil layers decreased. After that ECe increased in all the soil layers at 2.89 m waterable depth. ECe of 0-30 cm was considerably reduced. Never the less, ECe of 0-30 cm and 30-60 cm soil layers increased with 2.28 m waterable depth. ECe of all the soil layers reduced at 2.53 m waterable depth due to 68 cm of irrigation water application to wheat and sorghum fodder as well as 43.87 cm of rainfall occurrence. Later on, ECe increased in all the soil layers due to fallowing after (harvesting of sorghum fodder), low rainfall 4 cm, high temperature, evaporation and low relative humidity. Even then, ECe of 0-30 cm soil layer was 7.77 dsm-1 lower than the initial ECe of the soil. During cropping salts were reduced in the 0-30 cm soil layer. The result is in conformity with the findings [12]. ECe of 0-30 and 30-60 cm soil layers increased at 2.28 m waterable depth due to sifting of salts from upper to the lower soil layers by evaporation during the period between the two crops. ECe increased at 2.28 m waterable depth due to considerable evapotranspiration losses by wheat and sorghum fodder [13], [14].

TABLE IV
INFLUENCE OF WATERABLE DEPTH ON ECE OF THE SOIL UNDER CROP COVER

Date	Waterable depth (m)	Soil depth (cm)				
		0-30	30-60	60-90	90-120	120-150
28.10.2006	1.15	12.80	5.66	5.01	3.11	2.61
05.3.2007	1.40	8.66	10.79	6.21	3.58	3.01
08.4. 2007	1.89	4.83	4.02	3.52	3.42	3.35
11.6. 2007	2.28	6.76	7.17	4.56	4.19	3.55
01.8. 2007	2.53	2.13	2.99	2.41	1.93	2.51
04.10.2007	2.89	5.03	6.84	5.47	6.05	3.87

C. Influence of waterable depth on ECe of the soil under cover crop and gypsum application

TABLE V
INFLUENCE OF WATERABLE DEPTH ON ECE OF THE SOIL UNDER CROP COVER AND GYPSUM APPLICATION

Date	Waterable depth (m)	Soil depth (cm)				
		0-30	30-60	60-90	90-120	120-150
28.10.2006	1.15	12.80	5.66	5.01	3.11	2.61
05.3.2007	1.40	8.68	5.77	3.14	2.80	2.53
08.4. 2007	1.80	10.59	4.75	5.39	3.46	3.44
11.6. 2007	2.28	11.20	11.60	6.16	4.05	2.66
01.8. 2007	2.53	4.37	4.89	3.76	2.46	3.54
04.10. 2007	2.89	5.57	5.34	6.08	3.31	5.14

Effect of waterable depth on soil electrical conductivity is presented in Table.V.The data indicate that with lowering of waterable from 1.15 m to 2.53 m depth, ECe of most of the soil layers decreased. Later on ECe increased in all the soil layers at 2.89 m waterable depth. However, ECe of 0-30 cm reduced considerably while that of 30-60 cm slightly as compared to 1.15 m waterable depth. Increase in ECe occurred at 2.28 waterable depth. ECe of most of the soil layers reduced at 2.53 m waterable depth due to 68 cm of irrigation water application plus 43.87 cm of rainfall. After that ECe increase in all the soil layers due to fallowing after (harvesting of sorghum fodder), low rainfall (4 cm), high temperature, evaporation and low relative humidity. Even then ECe of 0-30 cm layer lowered significantly while that of 30-60 cm layer slightly as compared to initial values. Cropping reduced salts in the uppermost 0-30 cm soil depth as found [15]. ECe of most of the soil layers increased at 2.28 m waterable depth, possibly due to application of gypsum in the absence of requisite leaching [16] and also due to evaporation from soil surface during the pre-monsoon period when the relative humidity is low and evaporation in high. Evapotranspiration losses by wheat and sorghum fodder were considerable at 2.28 m waterable depth which also enhanced ECe of the soil [15].

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D. Influence of water table depth on SAR of the soil without crop cover (fallow)

Influence Effect of water table depth on sodium absorption ratio under fallow soil is presented in Table.VI. The data show that with lowering water table fro 1.5 m to 2.89 m depth the SAR of 0-30 cm soil layer was reduced from 53.86 to 42.27 while in the lower four soil layers i.e. 30-60 cm, 60-90 cm, 90-120 cm and 120-150 cm it remained d somewhat similar to the initial stage. SAR values showed an increasing trend from bottom to the top soil layers as was the case at the starting of the experiment, indicating an upward movement of soil moisture and salts. The lowest values were recorded in Feb. and March after which slight increase occurred. SAR of 0-30 cm soil layer decreased at the end of the experiment with 47.87 cm of scattered rainfall occurrence plus 10.6 cm pre-sowing water application during the entire period of research. Although SAR of 0-30 cm soil deceased slightly but even then it was the highest amongst the treatments under study. The data reveals that in fallow soil, the enhanced capillary action ultimately increased SAR of the fallow soil gradually from the lowest to the uppermost soil layer. These findings are in concurrence with those [13], [17].

TABLE VI
INFLUENCE OF WATER ABLE DEPTH ON SAR OF THE SOIL WITHOUT CROP COVER

Date	Waterable depth (m)	Soil depth (cm)				
		0-30	30-60	60-90	90-120	120-150
28.10.2006	1.15	53.86	30.30	29.22	20.32	17.46
05.3.2007	1.40	33.99	26.04	22.17	13.25	10.56
08.4. 2007	1.89	33.22	16.20	17.99	11.51	10.47
11.6. 2007	2.28	35.72	28.70	15.03	16.40	17.39
1.8. 2007	2.53	36.53	21.17	13.14	11.62	14.26
4.10. 2007	2.89	42.57	30.61	23.55	18.26	16.11

E. Influence of waterable depth on SAR of the soil under crop cover

Effect of waterable depth on sodium absorption ratio of the soil is presented in Table.VII. The data show that SAR of all the soil layers was reduced when waterable was lowered from 1.15 to 2.53 m depth. After that the SAR of all the soil layers increased at 2.89 m waterable depth. However, SAR of the uppermost soil layer (0-30 cm) was considerably reduced as compared to initial value. SAR showed an increasing trend at 2.28 m waterable depth. SAR of all the soil layers was reduced considerably at 2.53 m waterable depth with 68 cm of irrigation water application plus 43.87 cm of rainfall. After that the SAR increased at 2.89 m waterable depth due to fallowing, low rainfall, high temperature, evaporation and low relative humidity. SAR of the uppermost soil layer was reduced considerably. The result is accordance with the work [18],[19]. SAR showed somewhat increasing trend at 2.28 m waterable depth due to rapid capillary action during the hot and dry pre-monsoon period.

TABLE VII
INFLUENCE OF WATERABLE DEPTH ON SAR OF THE SOIL UNDER CROP COVER

Date	Waterable depth (m)	Soil depth (cm)				
		0-30	30-60	60-90	90-120	120-150
28.10.2006	1.15	53.86	30.30	29.22	20.32	17.46
05.3.2007	1.40	33.92	38.29	23.0	12.29	10.55
08.4. 2007	1.89	17.78	13.76	13.16	10.45	11.33
11.6. 2007	2.28	42.15	27.06	21.87	24.10	24.94
01.8. 2007	2.53	11.47	13.63	11.60	10.71	10.11
04.10. 2007	2.89	21.48	32.90	27.69	32.14	19.42

F. Influence of water table depth on SAR of the soil without crop cover (fallow)

TABLE VIII
INFLUENCE OF WATER TABLE DEPTH ON SAR OF THE SOIL WITHOUT CROP COVER (FALLOW)

Date	Waterable depth (m)	Soil depth (cm)				
		0-30	30-60	60-90	90-120	120-150
28.10.2006	1.15	53.86	30.30	29.22	20.32	17.46
05.3.2007	1.40	12.55	16.51	7.73	6.72	5.34
08.4.2007	1.89	18.16	10.57	13.99	8.42	6.25
11.6.2007	2.28	40.38	38.46	29.92	14.20	11.87
01.8.2007	2.53	6.09	8.84	9.08	7.57	7.16
04.10.2007	2.89	8.38	17.54	11.15	11.40	18.84

Effect of waterable depth on sodium absorption ratio of the soil is presented in Table. VIII. The data reveal that with lowering of waterable from 1.15 m to 2.53 m depth; SAR of all the soil layers was reduced considerably as compared to initial values. After that the SAR of all the soil layers increased. However, SAR of four the upper soil layers was considerably lowered as compared to the initial values. SAR of the two upper soil layers increased at 2.28 m waterable depth. SAR of all the soil layers was reduced considerably at 2.53 m waterable depth due to 68 cm of irrigation water application plus 43.87 cm of rainfall. Later on the SAR increased at 2.89 m waterable depth due to fallowing, after (harvesting of sorghum fodder), low rainfall (4 cm), high temperature, evaporation and low relative humidity. Even then the SAR of the four upper soil layers was reduced considerably as compared to the initial values. The result is in conformity with the findings [20]. SAR of the two upper soil layers increased at 2.28 m waterable depth due to application of gypsum in the absence of requisite leaching [21]-[23] also due to high evaporation during the hot and dry pre-monsoon period, hindering downward movement of the soil water.

IV. CONCLUSIONS

Soil moisture depletion was directly proportional to lowering of watertable. With the application of irrigation water (58cm) pH, EC and SAR were reduced in cropped plots; reduction was higher in gypsum applied plots than non-gypsum plots. In case of fallowing, there was increase in pH, EC, while slight reduction occurred in SAR values. However, soil salinity showed an increasing upward trend under fallowing and its value in 0-30 cm soil layer was the highest amongst the treatments.

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