Effect of Depth and Salt Concentration of Ground Water on Salinization of Soil

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Large areas of irrigated soils in the Nile Delta and Valley suffer from salinity due to the presence of saline ground water near to the surface.

The presence of a high ground water table when the ground water is of a high soluble salt content under arid and semiarid climates leads to the translocation of salts throughout the soil profile by capillary action enhanced by high evapotranspiration, thus resulting in what is termed "salt affected soil".

The critical levels and salt content of ground water with regard to their effect on the salinization process have received some attention. KOVDA [2] reported that the critical level depends upon the salinity of the ground water. ELGABALY [1] studied causes of secondary salinization of Egyptian soils in relation to irrigation and ground water.

Since salt accumulation depends, among other things, upon the depth and the salt concentration of ground water, the present work deals with the study of the effects of two levels of ground water each having three different levels of salt concentration, on salt accumulation during a cropping pattern including cotton, fallow and barley.

Materials and methods

Lysimeters (1×1×2 meters) fitted with side drain tubes fixed at the depth required and feeding tubes at their bottom, to maintain the required water-table depth were used. The soil selected for the study contains 28% of very fine $CaCO_3$, with a hydraulic conductivity of 0.48 cm./hour. It contains 59.18, 5.14 and 25.68% of sand, silt and clay respectively.

The lysimeters were filled with the soil and each treatment was replicated three times. During the experiment the ground water was maintained at depths of 50 (d_1) and 90 cms. (d_2). Three levels of salinity of ground water were used the compositions of which are given below:

Salinity level	E. C. mmhos./cm.	Anions me./l.				Cations me./l.			
		CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
S_1	10.7	0.95	2.25	82.8	10.7	6.41	15.59	297	1.98
S_2	32.0	0.95	1.89	217.6	32.1	15.44	54.28	235	5.31
S_3	58.4	0.95	1.89	543.0	62.9	28.99	105.50	460	10.65

The lysimeters were planted with cotton, followed by a fallow period, then again planted with barley. Composite samples representing each treatment were taken at depths of 20 cm. at the following dates.

Date of sampling	Treatment
28. 7.1962.	Before irrigation of cotton
1. 8.1962.	After irrigation of cotton
20. 8.1962.	After irrigation, end of growing season of cotton
23. 9.1962.	Start of fallow period
6. 11.1962.	End of fallow period
8. 1.1963.	After irrigation of barley
27. 3.1963.	After irrigation, end of growing season of barley

The samples were analysed for total soluble salts, Na^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, CO_3^{2-} and HCO_3^- using standard methods [3].

Results and discussions

The results are shown in Tables 1—4. and Figures 1—4.

Figure 1. shows the relation between total soluble salts in the upper 20 cm. layer, and date of sampling at two different depths and three levels of salinity of the ground water. From Figure 1. it is clear that soil salinity

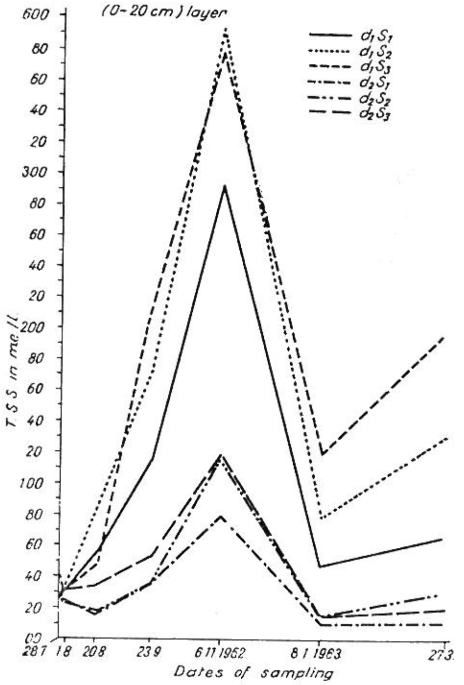

Fig. 1.
Changes in salinity of the surface layer with depth, salinity of ground water and date of sampling

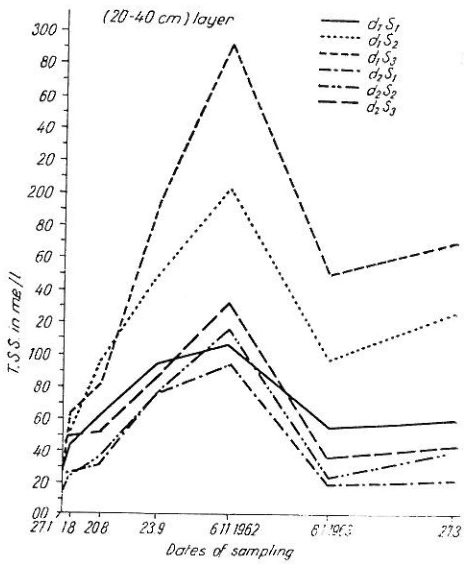

Fig. 2.
Changes in salinity of the subsoil with depth, salinity of ground water and date of sampling

Table 1.

Change in chloride concentration in the 0—20 cm layer with depth and salinity of ground water

Date of sampling	Cl^- concentration me./l.						Treatment
	d_1 = 50 cm.			d_2 = 90 cm.			
	S_1	S_2	S_3	S_1	S_2	S_3	
28. 7.1962.	10.96	9.79	8.39	3.96	9.79	34.51	Cotton before
1. 8.1962.	11.97	13.55	8.81	4.97	9.03	19.87	Cotton after irrigation
20. 8.1962.	29.17	43.45	26.07	6.21	7.14	22.97	End of cotton vegetation
23. 9.1962.	79.02	140.47	167.84	20.66	21.17	38.22	Fallow
6. 11.1962.	251.07	351.20	329.92	40.15	77.40	93.36	Fallow
8. 1.1963.	28.69	45.32	67.99	4.34	4.10	6.27	Barley after irrigation
27. 3.1963.	39.23	101.16	147.62	5.68	17.03	12.13	End of barley vegetation

S_1 = 6 000 p. p. m. S_2 = 18 000 p. p. m. S_3 = 35 000 p. p. m.

in the surface layer tends to increase slightly with time during the growing season of cotton. This is followed by a sharp increase in salinity during the fallow period at all three levels of salinity and the two depths of ground water. When the ground water table was kept at 50 cm. (d_1), the increase in salinity in the upper 20 cm. was very pronounced at all three levels of salinity. At this shallow depth small differences were observed due to differences in the salinity of the ground water at the two highest levels of salinity. However, both were higher than the lowest level of ground water salinity. The salinity level in the soil was greatly reduced following irrigation which may indicate the importance of the short frequences between irrigation to maintain the salt concentration in the soil at a level suitable for plant growth.

Table 2.

Changes in chloride concentration in the 20—40 cm. layer with depth and salinity of ground water

Date of sampling	Cl^- concentration me./l.						Treatment
	d_1 = 50 cm.			d_2 = 90 cm.			
	S_1	S_2	S_3	S_1	S_2	S_3	
28. 7.1962.	12.13	28.91	11.19	5.13	11.66	30.78	Cotton before irrigation
1. 8.1962.	19.42	21.23	16.71	8.36	8.81	33.20	Cotton after irrigation
20. 8.1962.	36.0	57.42	49.35	14.90	14.28	35.38	End of cotton vegetation
23. 9.1962.	73.33	130.14	163.71	38.22	52.68	54.74	Fallow
6. 11.1962	79.82	178.5	246.71	44.51	81.27	93.36	Fallow
8. 1.1963.	38.33	67.02	97.88	6.75	8.20	18.80	Barley after irrigation
27. 3.1963.	39.74	99.87	132.65	10.06	24.26	25.29	End of barley vegetation

S_1 = 6 000 p. p. m. S_2 = 18 000 p. p. m. S_3 = 35 000 p. p. m.

Table 3.

Changes in sodium concentration in the 0—20 cm. layer with depth and salinity of ground water

Date of sampling	Na^+ concentration me./l.						Treatment
	d_1 = 50 cm.			d_2 = 90 cm.			
	S_1	S_2	S_3	S_1	S_2	S_3	
28. 7.1962.	16.52	10.71	12.64	5.56	13.49	19.74	Cotton before irrigation
1. 8.1962.	15.13	14.67	14.11	8.35	12.25	13.67	Cotton after irrigation
20. 8.1962.	23.71	36.28	22.84	8.08	8.67	17.76	End of cotton vegetation
23. 9.1962.	58.06	78.58	106.60	14.61	13.11	18.84	Fallow
6. 11.1962.	129.35	163.63	178.39	27.23	37.48	42.13	Fallow
8. 1.1963.	26.20	32.72	53.22	4.53	5.74	4.93	Barley after irrigation
27. 3.1963.	33.47	61.39	95.12	6.16	12.65	10.02	End of barley vegetation

S_1 = 6 000 p. p. m. S_2 = 18 000 p. p. m. S_3 = 35 000 p. p. m.

If we now examine the effect of lowering the depth of the ground water table to 90 cm. (d_2) we find that the general trend is similar to that of the 50 cm. depth while the magnitude of change is much smaller. That is to say soil salinity is less than $^1/_3$ of its level at the 50 cm. depth. In addition, the effect of difference in the salinity of the ground water is not very pronounced. Therefore, we can conclude that the depth of ground water contributes more to the salinization of the soil surface than does the salinity level of ground water.

Figure 2. shows the same relations as Figure 1. but for the 20—40 cm. layer. Here, we find that at the 50 cm. depth of ground water the difference

Table 4.

Changes in sodium concentration in the 20—40 cm. layer with depth and salinity of ground water

Date of sampling	Na^+ concentration me./l.						Treatment
	d_1 = 50 cm.			d_2 = 90 cm.			
	S_1	S_2	S_3	S_1	S_2	S_3	
28. 7.1962.	16.52	10.71	12.64	5.56	13.49	19.74	Cotton before irrigation
1. 8.1962.	15.13	14.67	14.11	8.35	12.25	13.67	Cotton after irrigation
20. 8.1962.	23.71	36.28	22.84	8.08	8.67	17.76	End of cotton vegetation
23. 9.1962.	58.06	78.58	106.60	14.61	13.11	18.84	Fallow
6. 11.1962.	129.35	163.63	178.39	27.23	37.48	42.13	Fallow
8. 1.1963.	26.20	32.72	53.22	4.53	5.74	4.93	Barley after irrigation
27. 3.1963.	33.47	61.39	95.12	6.16	12.65	10.02	End of barley vegetation

S_1 = 6 000 p. p. m. S_2 = 18 000 p. p. m. S_3 = 35 000 p. p. m.

in the salinity level of ground-water is reflected in the salinity of the soil, i.e. S_3 S_2 S_1 at all dates of sampling. Similar effects of cropping, fallow, and irrigation, reported for the 0—20 cm. layer were observed. The maximum level of soil salinity attained in this layer is less than in the 0—20 cm. layer which indicates that salts tend to accumulate in the surface layer where evaporation is most active.

At a 90 cm. depth of ground water the effect of difference in the level of ground-water salinity on soil salinization is not very pronounced, here we find that soil salinity in this layer is almost equal to that in the 0—20 cm.

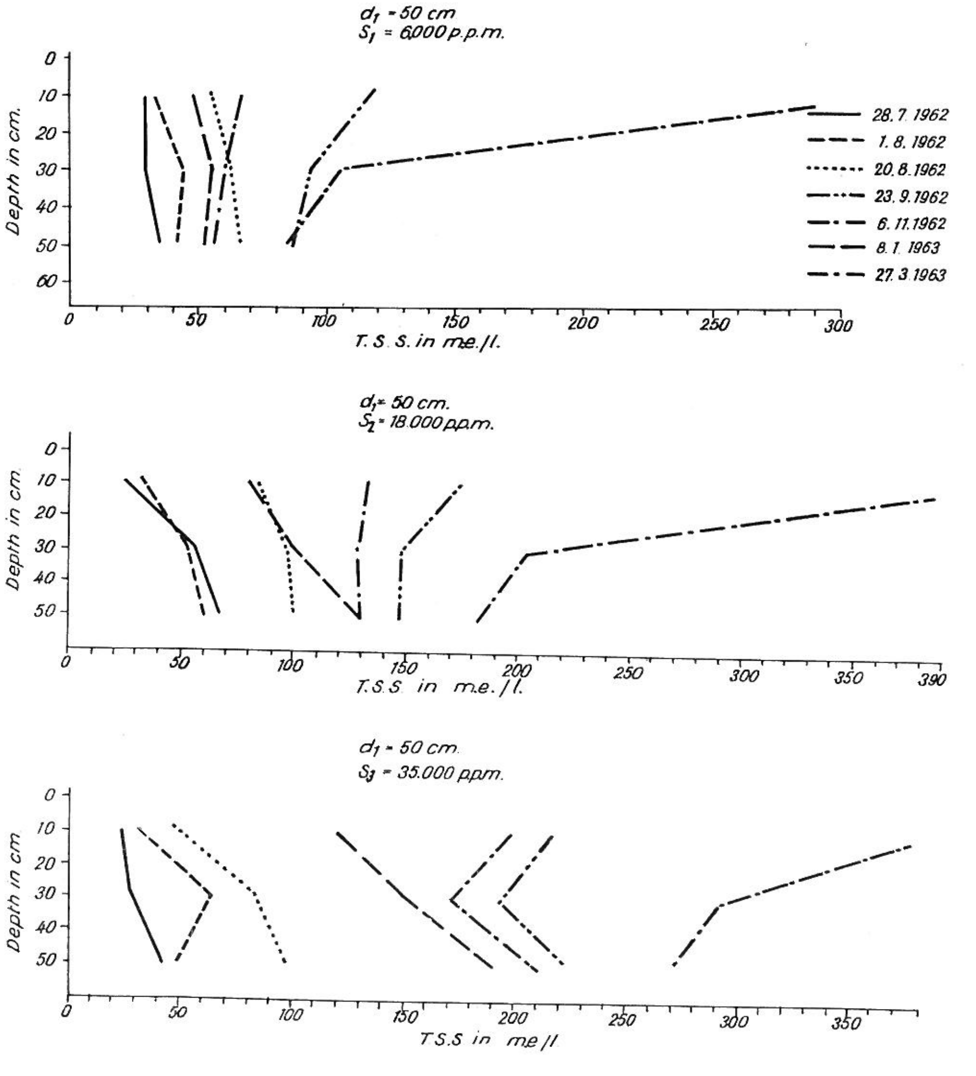

Fig. 3.
Distribution of salts in the soil profile at a depth of 50 cm and three levels of salinity

layer which may indicate that the effect of the depth of ground water is reflected more in the top layer.

Figure 3. shows the changes in total soluble salts with depth, at different dates for the three different salt concentrations of ground water at a depth of 50 cm. It is clear that the difference between the maximum and minimum

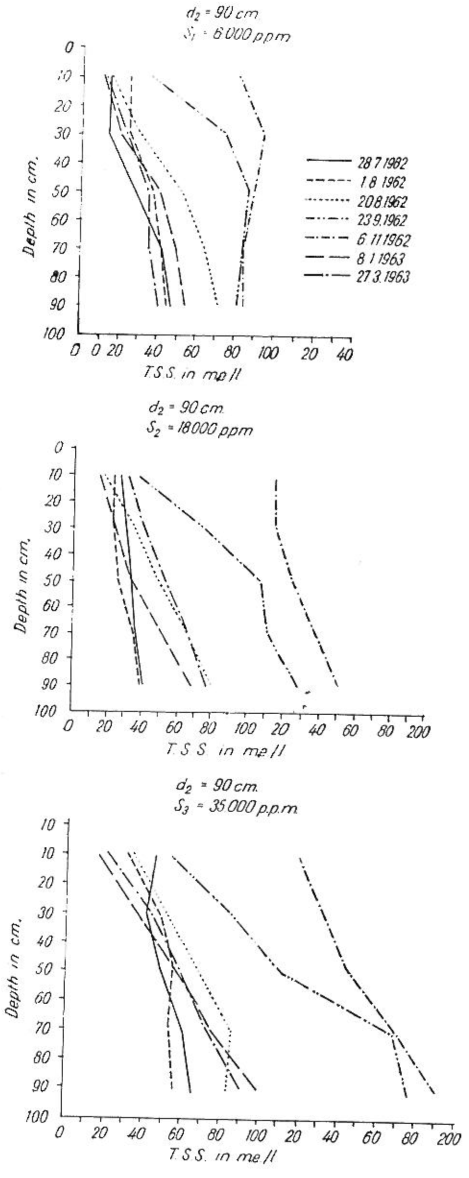

Fig. 4.
Distribution of salts in the soil profile at a depth of 90 cm and three levels of salinity

salinity in the surface layer is very great at all three levels of concentrations. This difference between the maximum and minimum values is greatly reduced with depth. However, it became larger with the increase in salinity of the ground water.

Figure 4. shows the changes in total soluble salts with depth at different dates for a depth of ground water of 90 cm. Here the difference between the maximum and minimum salt concentration does vary greatly with depth. This may indicate that when the ground water is at a depth of 90 cm. the upward movement is not very active. In addition, soil salinity is much lower than when the water table is at 50 cm.

The changes in the chloride and sodium concentrations in the soil with time, depth, and salinity of ground water are given in tables 1—2. and 3—4. respectively.

It is to be observed that they follow the same trends followed by total soluble salts previously discussed as influenced by depth, salinity of ground water, type of crop, fallow period, and irrigation. The pattern of change can be summarized as follows:

1. The concentration of Cl^- and Na^+ increased during the fallow period.

2. The effect of depth of ground water on Cl^- concentration in soil was more pronounced than was the effect of its salinity level.

3. The concentration in the top 0—20 cm. layer was higher than in the next 20 cm. particularly during the fallow period and at a 50 cm. depth of ground water.

4. The concentration changes of sodium generally followed those of chloride.

5. The higher the sodium and chloride concentrations are in the ground water, the higher are their concentrations in the soil. This is particularly true for the ground water depth of 90 cm.

These results indicate that the so called critical depth and salt concentration defined as the depth and salt concentration at which the processes of soil salinization start especially in the surface layer depend upon the depth, and salinity level of ground water, climate and irrigation regime.

It seems that the critical depth is modified by the concentration of salts in the ground water. The higher the salt concentration of the ground water is, the deeper the critical level of ground water. It follows, that the higher the ground water table is the lower the critical salt concentration is in the ground water. Unpublished data from this laboratory indicate that the texture plays an important role in the so called critical depth and concentration as well as in the distribution of salts in the soil profile.

Summary

The effects that depth and salt concentration of the ground water, cropping pattern and irrigation regime have on soil salinization have been studied. Two depths and levels of salts were included. Results indicate that above a certain salinity level, the depth of the ground water is more important than is the level of its salinity, and is a contributing factor to soil salinity, particularly in the surface layer. The depth and salinity of ground water has very little effect on salinity of the subsoil. This is conditioned more by cropping pattern and irrigation regime.

References

[1] ELGABALY, M. M.: Secondary salinization of Egyptian soils in relation to irrigation and ground water. Tashkent Internat. Hydro-geological symposium. 1962. (In Press.)

[2] KOVDA, V. A.: Salinity problems of irrigated soils in Egypt. Report submitted to N. R. C. and Des. Inst. Published in 1962 by the Bul. Dest. Inst. 1958.

[3] RICHARDS, L. A.: United States Salinity Laboratory Staff. Diagnosis and improvement of saline and alkali soil. U. S. D. A. Handbook 60. 1954.

Влияние глубины залегания и концентрации солей в грунтовых водах на засоление почвы

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Резюме

Исследовано влияние глубины залегания грунтовых вод, содержания в них солей, а также севооборотов и метода орошения на процесс засоления почвы.

Изменения содержания растворимых солей в почве зависят от глубины залеганиях и минерализации грунтовых вод, выращиваемой культуры или продолжительности содержания почвы под паром и способа орошения. Эти изменения можно суммировать следующим образом:

1. Концентрация Cl^- и Na^+ в период содержания почвы под паром возрастает.
2. Глубина залегания грунтовых вод оказывает большее влияние на концентрацию Cl^-, чем степень минерализации в них солей.
3. Концентрация солей в верхнем 20 см слое почвы выше, чем в следующем 20 см слое, особенно под паром при залегании грунтовых вод на глубине 50 см.
4. Концентрация натрия в основном слагается так же, как и концентрация хлоридов.
5. Чем выше концентрация натрия и хлора в грунтовой воде, тем выше их концентрация и в почве. Это справедливо особенно в том случае, когда грунтовые воды залегают на глубине около 90 см.

Эти результаты указывают на то, что так называемые критическая глубина и критическая концентрация, то есть та глубина и концентрация при которых начинается процесс засоления почвы, особенно в верхних слоях почвы, зависит от глубины залегания грунтовых вод, и степени их минерализации, а также от климата и способа орошения.

Критическая глубина залегания зависит от степени минерализации грунтовых вод. Чем выше концентрация солей, тем глубже должен находиться критический уровень залегания грунтовых вод. Из этого следует, что чем выше уровень залегания грунтовых вод, тем меньше критический уровень концентрации солей в них. Неопубликованные данные нашей лаборатории указывают и на то, что механический состав почвы играет большую роль с точки зрения критического уровня грунтовых вод и их концентрации, также как и распределения солей по почвенному профилю.