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The effect of irrigation with drainage water on some chemical soil properties and the yield of different field crops

Samia EL-GUINDY
Gamal Abd EL NASSER
Attiat ABU BAKR
Laila EL SISSI
Drainage Research Institute
Water Research Center - Cairo - Egypt

At the request of the Egyptian Ministry of Irrigation, this study on the use of drainage water for agriculture in Egypt was carried out with the cooperation of the Egyptian Drainage Research Institute and the Mediterranean Agronomic Institute of Bari, Italy.

One of the main objectives of this project was to study the relation between irrigation water quality and soil properties on plant growth and crop yield in order to recommend suitable cropping patterns that can be adopted according to the quality of drainage water, physical and chemical properties of the soil.

To carry out this study, an experimental area of 2.5 fedd. was established in Fayoum Governorate (see **Map***) where drainage, mixed and fresh water have been used for irrigation of common crops in the Fayoum area. Data concerning soil and crops were collected frequently and analysed. This paper presents the results of the effect of irrigation water quality on some chemical soil properties and the productivity of some field crops.*

I - Material and methods

1. Execution of the experiment

The area was divided into 12 equal plots separated from each other by earth dykes (see **Map**). The six western plots were used for cultivating one crop and the six eastern plots for the other crop. Irrigation water was pumped from the mixing reservoir to the plots through a pipe line on the dyke at the middle of the area separating the two crops: wheat and onion, followed by maize and summer tomato, followed by pepper and winter tomato. Nitrogen and phosphorus fertilizers were applied. Fresh water (400 ppm, adj. SAR 5), drainage water (1,700 ppm, adj. SAR 22) and mixing water (1,200 ppm, adj. SAR 18) were used for irrigation. Water application and frequency were according to the crop water requirements and soil moisture (El Guindy, 1986).

During the summer season of 1986 it was noticed that in certain plots, big areas without vegetation occured. The soil of these areas was very carefully studied mainly for the composition of the exchange complex and the adsorption of sodium.

The value of ESP was found to be 30 which was a sign of the need to improve the soil.

After the harvest of the summer season of 1986, soil improvement in the area began with the installation of a tile drainage system followed by ploughing and addition of gypsum to half of the plots at a rate of 2 tons/fed. Leaching was carried out in the area two times.

2. Methods and techniques of sampling and analysis

Three soil samples were taken to represent each plot for three times during each crop season. Those samples were collected at 25 cm intervals to a depth of 1 meter. Irrigation drainage and mixed water samples were collected on a monthly basis. Groundwater samples were also collected during soil sampling.

The samples were analysed at the DRI laboratory for: particle size distribution, electric conductivity soluble cations as well as anion, CaC03, cation exchange capacity and exchangeable sodium percentage. The harvest of crops was done by hand in time and the yield was determined for each plot separately.

II - Results and discussions

1. The effect of irrigation water quality on soil properties

From the investigation of the salinity development over a depth of 2 m it was found that the six treatments have led the soils rapidly to clearly different salinity levels and that different plots with the same initial salinity levels reacted in the same way (**Figure 1**).

It is clear from the figure that in the plots with initial soil salinity (EC) higher than 4 mmhos/cm, all the treaments, even irrigation with drainage water (1,700 ppm), lead to soil desalinization.

The irrigation water moves downwards carrying the dissolved salts from the upper layer to the lower one. Again the pores of this layer are filled and the water moves to a lower layer and so on.

The EC value decreased in the first winter season from 11 and 8.5, when the wheat was irrigated with drainage water (1,800 ppm) and mixed water (1,200 ppm) respectively, to 6 and 4 mmhos/cm. With continuous irrigation with the same quality in the other seasons, the salinity never rises to the initial case.

Salts increased and accumulated in the plots which have initial EC less than 4 mmhos/cm. It can be seen from the figures that with wheat crops the salinity increased in the plot which was irrigated with mixed water from 3.5 mmhos/cm to 7 mmhos/cm. In plots cultivated with onions and with an initial soil salinity of 2.5 mmhos, the salinity increased at the end of the season to 7 mmhos after irrigation with drainage and mixed water.

In the period between harvest of the 1985 winter season and cultivation of the 1986 summer season, the figures show slight increases of soil salinity because of no water application in this period. The saline water evaporated from the deep layers again to surface layers carrying with it the soluble salts. During the 1986 summer season soil salinity decreased in all the treatments of tomato crops to an average value of 2.5 mmhos/cm due to irrigation and leaching. The same trend was observed with maize crops.

As mentioned before, after the 1986 summer season the field was provided with a drainage system.

In examining the results obtained after leaching and mixing with gypsum, it seems that the five treatments had a significant effect upon the removal of exchangeable sodium. The ESP values were lower after one cropping season in spite of the fact that gypsum needs a long time to affect alkalinity due to its low solubility.

It was also noticed that the installation of the tile drainage system changed the ESP value due to the leaching of sodium salts. On the other hand, drainage with application of gypsum speeded up the process of exchange between the clay complex and the gypsum.

2. The effect of irrigation water quality on yield

Winter crops (1985-86 season)

Taking into consideration that the threshold value of wheat is 7 mmhos for soil and about 3,000 ppm for irrigation water (Nijland and El Guindy, 1983; FAO, 1975), no decrease in yield was expected due to irrigation with saline water with a maximum value of 1,200 ppm. However, from **Table 2**, it was clear that there was a difference between the yield of various plots. This difference was mainly due to the difference in soil alkalinity. **Figure 2** shows the relation between wheat yield and ESP value. It can be noticed that the reduction in yield was 21% and began with ESP 17. The maximum grain yield obtained was 2.5 ton/fed. compared with the average yield in the Fayoum Governorate of 2 ton/fed.

The results obtained are in agreement with the results of various investigators (Nijland and El Guindy, 1983; FAO, 1975). They concluded that the wheat crop can tolerate salinity with irrigation water up to 2,500 ppm without any drop in yield, compared to a 20% decrease when using irrigation water with salinity up to 4,000 ppm.

It is also clear from **Table 3** that the maximum yield of onions is 4 ton/fedd., while the average yield for Fayoum Governorate is 7.2 ton/fedd. This could be attributed to the fact that the onion plant is sensitive to salinity where the threshold value is 1.2 mmhos/cm for soil and about 600 ppm for irrigation water. The maximum yield was obtained when the average soil salinity of the top layer (0-50 cm) was about 3.0 mmhos/cm. The yield decreased with increasing soil salinity to reach the minimum 25 ton/fed. at a soil salinity of 8.5 mmhos/cm.

Summer crops (1986 season)

Due to the salinity and alkalinity spots which appeared in different parts of the field, tomato and maize plants failed to grow in these spots, specially tomatoes in plots 4 and 5 where the alkalinity was very high and few plants were grown. In addition to the sensitivity of maize to salinity, where the threshold value is 1.8 mmhos/cm for soil, 1.2 mmhos for irrigation water. This requires replanting several times, and thus there was no homogeneity in the field.

It is worthwhile to mention here that irrigation with fresh water during the whole period of growth gives the highest results in plant height, number of leaves, as well as fresh and dry weight of the yield, as shown in **Table 4**.

The highest grain yield (about 1.06 ton/fed.) obtained by the irrigation treatment commonly used by the farmer (fresh water) where the soil salinity and ESP values were low (3.5 mmhos/cm and 15), compared to the other treatments where the salinity and ESP values reached 6 mmhos and 24 respectively, reduces yield by about 56%. At the same time we can consider that the maximum yield obtained in this experiment is very low, compared with the Governorate production of 1.6 ton/fed.

Tomato yields were determined and presented in **Table 5.** It can be noticed that the highest yields were obtained with the treatment of fresh water during the whole period (about 3.1 ton/fed.) While the lowest yields were obtained with the treatment of mixed or drainage water during the whole period of growth (about 0.57 ton/fed. Average tomato yields in Fayoum are about 7.3 ton/fed. The great reduction in yield in this experiment, compared to the yield of the governorate, could be attributed to the higher alkalinity where ESP value was higher than 15 in all the plots and reached 50 in some spots.

Winter Season 1987

The results of tomato and pepper yields, presented in **Table 6**, refer only to the first harvest. The results of this season are very clear compared with the results of the previous seasons, because the improvement of soil alkalinity gave a chance for the appearance of the effects of various irrigation water salinity treatments.

It can be clearly observed from this table that in the plots mixed with gypsum, high pepper yields were obtained from the plots irrigated with fresh water, followed by the plots irrigated during the first period of growth with fresh water. The lowest yield (with a decrease of 74%) was found in the plots irrigated with drainage or mixed water during the whole growing period.

On the other hand, the same table also shows that no trend could be shown due to various irrigation water treatments in the plots which were not mixed with gypsum and still have high ESP values. The ESP values of these plots decreased to

a small value after the installation of tile drains, but did not reach the safe value (< 15).

III - Conclusion

Irrigation with saline water decreases soil salinity as long as the salt concentration in the water is less than that of the soil. This means that with using drainage or mixed water with salts concentrations of (1,300 or 1,700 ppm) the soil salinity decreased if it was higher than 4 mmhos/cm (2500 ppm). On the other hand, using the same water quality in soils with salt concentrations less than 4 mmhos, salts will accumulate. Gypsum applications at a rate of 2 ton/fed., with installation of a tile drainage network decreased ESP value by about 30%.

Wheat can tolerate salinity in irrigation water up to 1,700 ppm where soil salinity was greater than 4 mmhos without appreciable decrease in the yield, but is affected by ESP higher than 13.

On the other hand, maize was very sensitive to soil salinity higher than 2.5 mmhos where the effect of water salinity could not be observed.

References

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Table 1: Percentage of exchangeable sodium removed

$$\frac{Na\ /CEC}{Na\ /CEC} \times 100$$

Plot No.	Initial	Drainage without Gypsum	Drainage with Gypsum
1	16	8%	10%
2	15	10%	20%
3	8	15%	22%
4	17	22%	40%
5	17	3.5%	15.8
6	19	31.5	43.2
7	19	28.0	32.0
8	18	34.4	21.0
9	27	48.0	38.5
10	25	32.0	48.0

Table 2: The effect of different irrigation water treatments on wheat yield

Plot No.	Treatment	Total weight Ton/fed. fresh	Straw Ton/fed. dry	Grain Ton/fed. dry
1	Fresh water from sowing to harvesting	11.50	4.90	2.10
2	Fresh water during the first stage and drainage water after	7.68	3.00	1.19
3	Fresh water during the first stage and mixed water after	10.50	4.30	1.64
4	Mixed water during all the period	7.35	3.60	1.22
5	Drainage water during all the period	8.40	4.38	2.13
6	Irrigation treatment commonly used by farmers	9.45	4.87	2.49

1 hectare + 2.4 feddan

Table 3: The effect of different irrigation water treatments on onion yield

Treatment	Yield ton/fed.
Fresh water from sowing to harvesting	3.864
Fresh water in the first period and drainage water after	2.604
Fresh water in the first period and mixed water after	4.116
Mixed water during all the period	2 520
Drainage water during all the period	2 688
Irrigation treatment commonly used by the farmers	2.352

Table 4: The effect of different irrigation water treatments on maize yield in ton/fed.

Treatment	Yield ton/fed.
Fresh water from sowing to harvesting	0.5948
Fresh water in the first period and drainage water after	0.7641
Fresh water in the first period and mixed water after	0.8768
Mixed water during all the period	0.4615
Drainage water during all the period	0.6909
Irrigation treatment commonly used by the farmers	1.0620

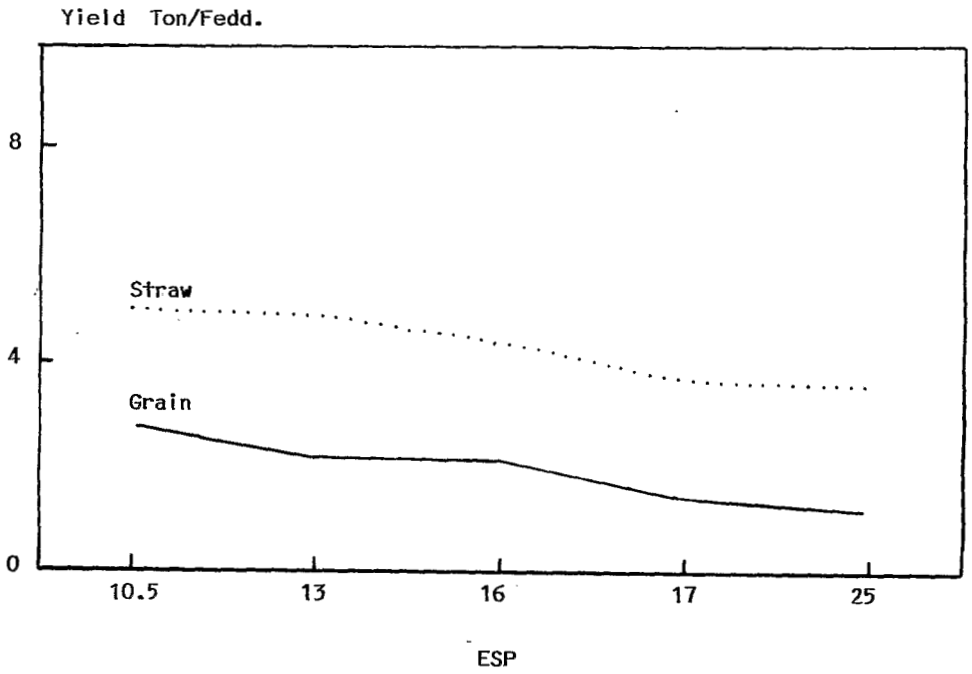
Table 5: The effect of irrigation water treatments on summer tomato yield

Treatment	Fresh weight of fruit kg/plot	ton/fed.
Fresh water from sowing to harvesting	391.0	3.10
Fresh water in the first period and drainage water after	203.2	1.61
Fresh water in the first period and mixed water after	177.0	1.40
Mixed water during all the period	72.0	0.57
Drainage water during all the period	134.5	1.07
Irrigation treatment commonly used by the farmers	242.5	1.93

Table 6: The effect of different irrigation water treatments on pepper and winter tomato in ton/fed.

Treatment	Tomato		Pepper	
	with gypsum application	without gypsum application	with gypsum application	without gypsum application
Fresh water	5.2	3.3	8.7	10.0
Fresh water + mixed water	2.6	3.4	8.6	8.7
Fresh water + drainage water	3.5	5.8	10.0	7.9
Mixed water	1.3	0.5	8.2	5.0
Drainage water	1.3	3.2	5.9	5.1
Treatment commonly used by the farmer	1.8 (without gypsum)	0.6	3.4 (without gypsum)	3.4
			44.8	40.0

Figure 1: The relation between wheat yield and ESP



Map: The location and the general lay out of experimental area