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Method of Using Drainage Water in Irrigation. 1- Its Effect on Soil Aggregation

M.Y. Tayel, M. Abd El-Hady and E.E. El-Dardiry

Soils and Water Use Department, National Research Centre, Dokki, Cairo, Bgypt.

GREENHOUSE and field experiments were carried out to assess the effects of drainage water usage on soil aggregation. Qulubia main drain water (DW) was used as a main source of irrigation mixed with canal water (CW) in the greenhouse experiment and alternatively with ground water (GW) in the field experiment. Data obtained indicated that DW can be used either mixed with CW (25: 75 or 50:50) or used alternatively with GW (2/2) on a clay loam soil for irrigation. This can improve soil structure and overcome some problems *i.e.* pumping, drain outlet, weeds and some plant diseases.

Keywords: Drainage, Canal, Ground water, Aggregation, Clay loam soil.

All over the world, irrigation water resources are becoming more scarce and of lower quality. Using lower quality water in irrigation and sustaining soil productivity is one of the urging research topics in the field of soil, irrigation and drainage.

Fathi and Milad (1974) found that a decrease in exchangeable sodium increases the soil structure factor. Fathi *et al.* (1969) found that an increase in values of dispersion ratio is usually accompanied by an increase in the values of exchangeable sodium percentage. Later, Fathi *et al.* (1971) found a highly significant positive correlation between the soil structure factor and soluble calcium and a highly significant negative correlation between soil structure factor and soluble sodium. Eissa (1986) pointed out that the soil structure factor decreased with increasing sodium percentage of irrigation water.

Abdel-Azim (1964) found a highly negative correlation coefficient between the total soluble salts and aggregation index, and a significant positive correlation between both the exchangeable calcium, magnesium and aggregation index. However, Zein El-Abdein (1969) found no relation between the amount of total soluble salts and aggregation on alluvial soil of Egypt. Jayavardan and Beattie (1979) reported that pores size index of alluvial soils markedly decreased with the reduction in electrolyte concentration especially in solutions of high SAR.

Tayel *et al* . (1980) studied the effect of Na : Ca : Mg ratios at different salt concentration (300 - 500 ppm) in irrigation water on stable aggregates percentage and aggregation index. They observed that the effect of Na: Ca: Mg ratios on the total water-stable aggregates percentage and aggregation index could be arranged in the following decreasing order 1 : 2 : 0 > 1 : 1 : 1> 1: 0 : 2. They also mentioned that the total water-stable aggregates percentages increased with increasing salt concentration and decreasing matric potential at the Na: Ca: Mg ratio of 1 :2 :0.

El- Arquan and Kaoud (1981) observed that the ESP comes at the first order to affect soil structure negatively, while exchangeable Mg and Ca % come at the second order with positive relation. Omar and Aziz (1982) found that the aggregates stability significantly decreased with increasing salinity in irrigation water. This may be due to the fact that soils irrigated with saline water containing high sodium cations, resulted in an increase in exchangeable sodium and reduction in exchangeable calcium plus magnesium.

According to Kandil (1990) the use of lower water qualities, especially from the drains only, decreased structure stability. This effect was more pronounced in the clay loam soils. The mean weight diameter (MWD) of soil aggregates was not affected significantly if a mixture of drain and canal waters was used for irrigation. The effects of five saline irrigation waters (0, 0.125, 0.25, 0.5 and 1 % using commercial NaCl in solution) were tested in factorial combination with three irrigation frequencies (every 2, 5, and 10 days) indicated that the structure stability index was reduced from initial values of more than 50 to 12 % with irrigation water containing 1 % NaCl.

The aim of the present work was to study the effect of using agricultural drainage water mixed with canal water and/or alternatively with ground water on soil aggregation.

Material and Methods

A loamy clay soil was selected at Moshtohour Village Toukh District, Qulubia Governorate, Egypt. The soil site is located near El-Qulubia main drain in order to assess the field experiment. Some characteristics of the used soil and water are presented in Tables 1 ,2.

Greenhouse experiment

The experiment was conducted using plastic pots with a 20 cm inside diameter and 22 cm height in the greenhouse of the Soil and Water Use Department, National Research Center, Dokki, Giza, Egypt. Top soil sample (0-25cm) from the experiment site (Moshtohour village-Toukh District) was dried, grinded, sieved through 0.3 cm sieve and mixed well. Ten kg of the soil were packed in each pot.

Wheat seeds (*Triticum sativum* L.cv. Sakha 69) were planted (10 seeds/pot). The plants were thinned to three plants / pot after two weeks. NPK fertilizers were added in the recommended doses. Growing season of wheat plants lasted 138 days.

After wheat corn (*Zea maize* L. cv. Hybrid 310) seeds were planted (10 seeds/pot). The plants were thinned after two weeks. NPK fertilizers were added in the recommended doses. Growing season of corn plants lasted 64 days.

Both wheat and corn experiments were irrigated using the DW:CW mixing ratios of 0:100,25:75,50:50,75:25 and 100:0. Irrigation was carried out twice a week, to restore soil water content to the 70 % from field capacity by weighing the pots.

Field experiment

The field experiment was divided into fifteen plots each (108 m^2) leaving one meter apart to avoid irrigation treatment effects. Superphosphate (P_2O_5 15%) at the rate of 200 kg /fed. (fed =4200 m^2) in both first and second crops were added before seedbed preparation and ploughed in top soil.

In the winter season, wheat (*Triticum sativum* L.cv. Sakha 69) seeds were planted. Ammonium nitrate was added at a rate of 150 kg /fed~at three equal doses, the plants were harvested 10 cm above soil surface. Growing season of wheat plants lasted 163 days.

TABLE 1. Some Soil *characteristics .

Parameter	Value	Parameter	Value
Particle size distribution		EC (soil paste dSm^{-1})	0.67
Coarse sand %	1.28	pH (1:2.5 soil:water)	7.40
Fine sand %	26.62	Soluble cations (meq/l)	
Silt %	37.21	Ca^{++}	3.58
Clay %	34.89	Mg^{++}	2.50
Texture	Clay loam	Na^{+}	1.21
		K^{+}	0.12
Bulk density g/cm^3	1.26	Soluble cations (meq/l)	
Total porosity %	52.45	CO_3^{-}	0.00
		HCO_3^{-}	2.30
$CaCO_3$ %	3.57	Cl^{-}	3.57
Organic matter %	1.11	SO_4^{--}	1.54

*Soil used in both field and greenhouse experiments.

TABLE 2. Irrigation water characteristics.

Irrigation water	Ground	Drainage	Canal	DW : CW		
Parameters	100 %			75 : 25	50 : 50	25 : 75
pH	8.22	8.21	8.19	8.18	8.10	8.11
EC (dSm^{-1})	0.80	1.09	0.81	1.00	0.85	0.86
Soluble cations (meq/l)						
Ca^{++}	1.50	3.80	3.00	3.55	3.25	2.90
Mg^{++}	2.00	1.85	2.55	2.00	1.75	1.70
Na^{+}	3.63	5.25	3.41	4.46	4.00	3.90
K^{+}	0.01	0.07	0.01	0.03	0.02	0.02
Soluble anions (meq/l)						
CO_3^{-}	0.00	0.00	0.00	0.00	0.00	0.00
HCO_3^{-}	3.00	3.00	3.75	3.60	3.00	2.75
Cl^{-}	3.75	4.65	3.42	3.82	3.50	3.45
SO_4^{--}	0.40	3.32	1.81	2.62	2.52	2.32
SAR	2.79	3.13	2.04	2.67	2.53	2.57
Adj.SAR	5.30	6.26	4.08	5.87	5.06	5.14

In the summer season, corn (*Zea maize* L.cv.) seeds were planted in the same plots after wheat crop. The corn plants were thinned when they were 25 cm tall. The plots received 200 kg /fed. ammonium nitrate at four equal doses, two weeks between each. Growing season of corn plants lasted 106 days.

Crop water requirements were calculated after the FAO (1977). Irrigation was carried out using ground water (GW) and drainage water from Qulubia main drain (DW) alternatively using the irrigation treatments of DW/GW:0/all, 1/3, 2/2, 3/1, and all/0.

The experiments were completely randomized block design (3 replicates and five irrigation treatments) in factorial analysis for both greenhouse and field experiment.

Measurements

After harvesting corn aggregate stability and its size distribution were carried out and calculated according to Kernber and Chepil (1965). Mean weight diameter (MWD) was calculated from wet sieving data as follows:

$$\text{MWD (weight sieving)} = \sum_{i=1}^{n} \bar{X}_i \, W_i$$

Where

$\bar{X}_i$ = the mean wieght diameter of each size fraction .

W_i = the proportion of the total sample weight occurring in the corresponding size fraction, where the summation is carried out over all size fractions, including the one that passes through the finest sieve.

The initial characteristics of the soil were determined as follows:

- Total soluble salts were determined in soil paste extract using the electrical conductivity meter according to Jackson (1967).

- Soil pH was determined in 1 : 2.5 soil water suspension using pH meter after Dewis and Freitas (1970).

- Calcium carbonate percentage was determined volumetrically using Collins's calcimeter (Dewis and Freitas, 1970).

- Organic matter was determined according to Walkely and Black method (Jackson, 1967).

- Soluble cations (Na^{+}, K^{+}, Ca^{++} and Mg^{++}) and anions (CO_3^{--}, HCO_3^{-}, Cl^{-} and SO_4^{--} were determined in soil paste extract according to Richards (1954).

- Data of aggregation were subjected to analysis of variance according to Snedecor and Cochran (1980).

Results and Discussion

Greenhouse experiment

The effects of DW: CW mixing ratios on soil aggregates in the greenhouse is given in Table 3. The data reveal that increasing of the drainage water for irrigation from 0 (100% CW) to 100% (0% CW) increased the aggregation percent from 9.03 to 17.14 % and the mean weight diameter from 0.01 to 0.14 mm according to the irrigation treatment and aggregate size under study.

TABLE 3. Effect of mixing drainage and canal water on aggregation (greenhous experiment).

Irrigation treatment DW:CW	Aggregate size %				Total aggregates %			MWD (mm)		
	8.0-0.85	0.85-0.425	0.426-0.250	0.25-0.10	8.0-0.10	0.85-0.10	0.25-0.10	8.0-0.10	0.85-0.10	0.25-0.10
0:100	1.79	1.39	1.15	9.03	13.36	11.57	9.03	0.11	0.03	0.01
25:75	2.54	1.53	1.32	10.31	15.70	13.16	10.31	0.14	0.03	0.01
50:50	1.29	1.27	1.08	13.50	17.14	15.85	13.50	0.09	0.04	0.02
75:25	2.09	1.46	2.51	9.95	16.01	13.92	9.95	0.13	0.03	0.01
100:0	2.09	1.79	3.54	8.89	16.31	14.22	8.89	0.13	0.04	0.01
LSD 0.05	0.39	0.24	0.17	1.40	1.65	1.33	1.40	0.02	0.01	0.001

MWD = mean weight diameter

The increase in the percentage of aggregates varying in diameter 8.0 - 0.1 mm accounted to 17.51, 28.29, 19.84 and 22.08 % at the DW: CW mixing ratios: 25:75, 50: 50, 75: 25 and 100 : 0 relative to the 0 :100 one, respectively. The maximum aggregation percent was achieved in the DW : CW mixing ratio 50 : 50 regardless of the aggregate size. Differences in the percentage of aggregates (8.0 - 0.1 mm) between the DW: CW mixing ratio 0 :100 and any of other ratios were significant at the 5% level. Concerning the aggregates 0.8 -0.1 mm in diameter, their behavior was similar to the one mentioned before. In other wards, the DW: CW mixing ratios 25 : 75, 50 : 50, 75 : 25 and 100 : 0 increased the aggregation percent by 13.74, 36.99, 20.31 and 22.90% relative to the DW : CW mixing ratio of 0 :100, respectively. Differences in aggregation percent between any two mixing ratios was significant at the 5% level, except that between any two mixing ratios of 25 : 75, 75 : 25 and 100 : 0.

The percentage of the aggregates 0.25 -0.1 mm in diameter ranged from 8.89 - 13.50% according to the DW : CW mixing ratio. The changes in those percentages were: 14.17, 49.50, 10.19 and -1.55 % in the DW : CW mixing ratios of 25 : 75, 50 : 50 , 75 : 25 and 100 : 0 relative to the ratio : 0 :100, respectively.

Generally speaking, the percentage of aggregates (8.0 - 0.1 mm) in diameter for this clay loam soil was quite low. This was due to grinding and sieving the soil before filling the pots. Also, the pots were only planted for only two seasons.

Data presented in Table 3 indicate that the mean weight diameter ranged from 0.01 to 0.14 mm depending on the DW: CW mixing ratio and aggregate size. The response of the mean weight diameter to DW : CW mixing ratios was similar to that of the aggregate percent except for that of the 8.0 - 0.1 mm diameter aggregates at the DW : CW mixing ratio : 50 : 50. This drop in the mean weight diameter (0.09 mm) may be due to the lower percentage of the 8.0-0.85 mm aggregates (1.29%). Since sand sized aggregates are more favourable for plant growth, than very small and very large ones, attention will be given to aggregates having 0.85 - 0.1 mm diameter. Data on hand clearly indicate that the mean weight diameter of the 0.85 - 0.1 mm aggregates (total sand except the very coarse and the very fine sand according to the USA method for soil particles fractionation) varied from 0.01 to 0.04 mm depending on the DW: CW mixing ratio. For the 2nd and 3rd aggregate groups, Table 3 shows that the maximum (0.04 and 0.02 mm) and the minimum (0.03 and 0.01 mm) mean weight diameter were obtained with a DW : CW mixing ratio of 50 : 50 , and with the three mixing ratios : 0 : 100, 25 : 75 and 75: 25, respectively. Differences in mean weight diameter between the DW : CW mixing ratio 50 :50 on the one side and all the other ratios were significant at the 5% level. The exception to that was the difference between the mixing ratios 50 : 50 and 100 : 0 in the 0.85- 0.1 mm aggregates.

The positive effect obtained on soil structure as measured by both the total aggregation percent, and the mean weight diameter on the account of mixing DW and CW may be due to the expected changes in some soils solution characters i.e. SAR, potential salinity, permeability index and effective salinity (meq l^{-1} and Na %). These results are in agreement with those obtained by El-Banna *et al.* (1974,1982), Balba and Atta (1981), El-Nahal *et al.* (1983), Grattan *et al.* (1987), Rains *et al.* (1987), Rhoades (1987), Rhoades *et al.* (1988), Kandil (1990) and Sharma *et al.* (1998).

It could be concluded that mixing DW and CW for irrigation purposes in this clay loam soil could be profitable. The most promising DW : CW mixing ratio was 50 : 50 since it will save 50 percentage of the Nile water to be used for land reclamation. In addition it improved soil structure. Since agriculture consumes about 48 milliard m^3 annually and drainage water is estimated to be around 12 milliard m^3, the DW : CW mixing ratio 25:75 could be recommended. Otherwise, an irrigation rotation defining the canal water and canal : drainage mixed water users and the way of shifting from one to the other is a must.

Field experiment

Data on soil aggregates percent and their mean weight diameters under field conditions after planting wheat and corn using drainage water (DW), and ground water (GW) in an alternative irrigations *i.e.* DW/GW: 0/all, 1/3, 2/2, 3/1 and all/0 are given in Table 4. The ranges of aggregate percent varied between 5.64 -13.24, 29.76 - 43.04, 11.31 - 13.70, and 8.75 - 10.61% for aggregate sizes of 8 - 0.85, 0.85 - 0.425, 0.425 -0.25 and 0.25 - 0.10 mm, respectively, according to irrigation treatment.

The total aggregate percent ranged between 62.97-69.80, 52.24-63.25, 8.75-10.61% for aggregates 8-0. 0.1, 0.85-0.1, and 0.25-0.10 mm in diameter, respectively, according to irrigation treatments (Table 4). However, aggregate mean weight diameter varied from 0.52 - 0.83, 0.24-0.32 and 0.011- 0.014mm. Differences in aggregate percent, total soil aggregate percent, and in their mean weight diameter between irrigation treatments were significant at the 5% level in most cases.

TABLE 4. Effect of alternative usage of drainage and canal water on soil aggregation (field experiment).

Irrigation treatment	Aggregate size (%)				Total aggregates %			MWD (mm)		
DW/GW	2.0-0.85	0.85-0.425	0.425-0.250	0.25-0.10	2.0-0.10	0.85-0.10	0.25-0.10	2.0-0.10	0.85-0.10	0.25-0.10
0/All	6.80	37.89	12.57	9.38	66.73	59.93	9.38	0.60	0.30	0.012
1/3	5.64	33.84	13.70	9.78	62.97	57.32	9.78	0.52	0.27	0.013
2/2	13.24	29.76	11.86	10.61	65.47	52.24	10.61	0.83	0.24	0.014
3/1	11.58	37.08	11.31	9.83	69.80	58.21	9.83	0.80	0.29	0.013
All/0	6.21	43.04	11.46	8.75	69.46	63.25	8.75	0.60	0.32	0.011
LSD 0.05	0.37	0.56	0.37	0.51	1.60	1.37	0.51	0.02	0.01	0.001

It is worthy to mention that the studied parameters were better under the field experiment relative to those under greenhouse experiment. The results reveal further that the irrigation treatment DW/GW (2/2) led to the maximum aggregate percent (10.61%), maximum total aggregate percent (10.61) and maximum aggregate mean weight diameter (0.014) for aggregate size of 0.25 - 0.10 mm (fine sand fraction). These aggregate size fractions are the most suitable for plant growth. Reasons for this have been discussed under the greenhouse experiment.

From the aforementioned results it is worthwhile to notice that the alternative irrigation treatment DW/GW (2/2) and the mixing ratio DW:CW (50:50) improved soil aggregation.

Using drainage water (mixed with canal and/or with ground water alternatively) of each mean collector drain in its command area may have benefits. It can save both surface and ground water, decreases the main collector drains cross section area, and decreases the problems of pumping, out - lets of the drains, weeds and some plant diseases.

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طرق إستخدام مياه الصرف الزراعى فى الرى
١- تأثيرها على تجمعات التربة

محمد يوسف طايل ، محمد عبد الهادى عبد الحميدو إبتسام ابراهيم الدرديرى
قسم الأراضى وإستغلال المياه ، المركز القومى للبحوث - القاهرة- مصر.

أجريت تجربتان فى الصوبة (بالمركز القومى للبحوث) والحقل لتقييم تأثيرات استعمال مياه الصرف الزراعى على تجمعات التربة. إستخدمت مياه مصرف القليوبى الرئيسى فى الرى سواء بالخلط مع مياه ترعة فى تجربة الصوبة أو بالتناوب مع مياه جوفيه فى تجربة الحقل. وتشير النتائج إلى أنه يمكن استعمال مياه الصرف الزراعى سواء بالخلط بمياه الترعة عند نسب خلط ٢٥: ٧٥، ٥٠:٥٠ أو استعمالها بالتناوب مع المياه الجوفيه فى رى أرض طينية طمييه. ويؤدى هذا الى تحسين بناء التربة والتغلب على بعض المشاكل على سبيل المثال الطاقة المبذولة فى رفع مياه المصارف وعدم وجود منفذ الصرف والحشائش وبعض أمراض النبات.