Effect of irrigation water quality on : 2- Atterberg limits, shear strength and suitable time for tillage of some North Delta clay Soils , Egypt

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ABSTRACT

As a result of the fresh irrigation water shortage in the North Nile Delta soils of Egypt , a study was conducted to evaluate the effect of irrigation water quality on soil tillage range and soil shear strength .because increasing sodicity and salinity in irrigation water affect both optimum tillage time and tillage results .

To achieve the aim of the study, a field experiments as well as, lysimeter experiment were conducted. In the field experiments, soil profiles were chosen from four locations irrigate with agricultural drainage water or agricultural drainage water with sewage water , or agricultural drainage water with sugar factory drainage water and fresh water as a control . lysimeter experiment was conducted with four treatments and three replications .
Artificial Salinization by (NaCland $CaCl_2$solutions) added to soil with irrigation water in calculated quantities (g/l) . the Ec values were (2,4,8 and 16 ds/m) and the SAR values were (10 , 20 and 30).

Results concluded that increasing salinity in irrigation water led to decreasing Upper plastic limit , Lower plastic limit , plasticity index and soil shear strength . The opposite trend was observed in the case of increasing SAR values in irrigation water .

INTRODUCTION

Water resources in Egypt are limited ,consequently improving irrigation system, increasing water use efficiency and drainage water reuse for irrigation is a must.

Egypt annual quota of Nile water is 55.5 billion m^3 used to fulfill the different water demands. Looking to the future ,the river Nile supply is rather limited and not sufficient to the requirement for drinking purposes ,industrial development agricultural, expansion and other purposes. It is well known that drainage water is generally saline, and may contain some polluting substances which minimize its utilization.

In many parts of the North Nile delta, farmers use drainage water to irrigate their fields, such water is considered the only source for irrigation purposes. Increasing salinity and sodicity in this water affect directly on soil physical properties, thus the suitable Time for tillage. Therefore, the main objective of the present work aims to Identify the suitable time for tillage in the saline and sodic soils.

MATERIALS AND METHODS

The present work was divided into two parts, the first part was concerning with profiles from North Nile Delta soils, irrigated by different sources of irrigation water qualities. The second part was lysimeter experiments, in which artificial salinization was carried out to analogue the previous field situations. To study and evaluate the effect of the different available sources of irrigation water in North Nile Delta, on soil properties, soil profiles were taken from three sites, which irrigated by agricultural drainage water mixed with sewage water, and agricultural drainage water with sugar factory drainage water.

Lysimeter experiments.

Lysimeter experiments were carried out at soil improvement and conservation research department, Sakha Agriculture Research Station. Soil was salinized artificially, using Nacl and $Cacl_2$ solutions to reach the level of (Electrical conductivity; 2, 4, 8 and 16 dsm-1), and sodium adsorption ratio (SAR: 10, 20 and 30). Four treatments with three replications, SAR was fixed with changed Ec.Each treatment included four plots; the area of each plot was 1 m^2 with 90 cm depth.

Atterberg limits:

Soil tillage range concludes three parameters, upper plastic limit (liquid limit), lower plastic limit (plastic limit) and plasticity range, as the difference between liquid limit and plastic limit.

Liquid limit: represents the minimum amount of water that a small soil sample needs to flow under standard conditions.

Plastic limit: is the water content at which the soil starts to loose cohesion due to the absence of water.

Liquid limit is determined by standard equipment to determine the moisture content at which the soil on two sides of a groove flows together after the dish which contains the soil has been dropped through a distance of 1cm 25 times.

The plastic limit is determined by measuring the soil moisture content at which the soil crumbles, when it is rolled down to a thread about 3 mm in diameter, **Atterberg (1911)**.The plasticity range calculated from the difference between the liquid limit and the plastic limit.

Soil shear strength:

Determination of soil strength under field conditions was done by, the van shear test **(ASTM, 1956)**. A van was driven into the soil to a known depth, then rotated to measure the torque (T max). The torque is related to soil cohesiveness as the equation:

$$C = \frac{T\,max}{\pi\left[\frac{dh^2}{2} + \frac{d^3}{6}\right]}$$

Where:

C =	Soil cohesiveness, N/cm^2
d =	Diameter of the van,cm
h =	The length of the van, cm
T max =	Torque measurements, N.m.

RESULTS AND DISCUSSION

Soil tillage range:

The consistency limits are used to define the different ranges of states, in which a cohesive soil can exist from liquid to solid. Atterberg setup five consistency limits, to illustrate the range of consistency **(Sridharm and Prakash,1998).** With time, only three of the abovementioned limits, namely, flow limit, the roll-out limit and the cohesion limit retained their recognition, and are now referred to as, the liquid, plastic and shrinkage limits, respectively. We are now interested in displaying three parameters of soil tillage ranges which considered very important in soil tillage, liquid limit (upper plastic limit), plastic limit (lower plastic limit) and plasticity range.

Data in Tables (1) and (2) show the effect of different irrigation water qualities on liquid limit, plastic limit and plasticity range, for winter and summer seasons, respectively. Data showed that values of liquid limit, plastic limit and plasticity range were lower with drainage water than that in fresh water, in both seasons. In the winter season, values of liquid limit decreased from 56.6% in case of fresh water to 56% in drainage water with sewage wastes and to 55.2% in case of drainage water with sugar factory wastes and to 53.7 in case of using agricultural drainage water. Also, values of plastic limits decreased from 28.4 % in case of using fresh water in irrigation to 27.6% in case of using agricultural drainage water with sewage wastes and to 27.3% in case of using drainage water with sugar factory wastes and to 26.4% in case of using agricultural drainage water. Consequently, plasticity range was decreased from 28.2% in case of using fresh water in irrigation to 27.8% in case of using drainage water with factory wastes and to 27.35% in case of using agricultural drainage water in irrigation , but the value was 28.27 in case of using drainage water with sewage wastes . Data, in Table (2) showed the effect of different sources in irrigation water qualities, on soil liquid limit, plastic limit and plasticity index in the summer season, and showed the same trend as in the winter seasons. Soil liquid limit values were (61.2, 59.9, 55.2 and 56.1) for fresh water, drainage water with sewage wastes, drainage water with sugar factory wastes and agriculture drainage water, respectively. The plastic limits values were (28.4, 27.6, 27.3 and 26.4%) for fresh water, drainage water with sewage wastes, drainage water with factory wastes and agriculture drainage water, respectively.

Plasticity index values were (32.07, 30.5 , 27.85) for locations1,2and 3 and increased slowly to 28.1 in the case of using agricultural drainage water(location No . 4) .

The effect of different qualities of Ec and SAR in irrigation water on soil tillage range are presented in Figs 1,2,3,4,5and 6 for winter and summer seasons, respectively.

Table (1) :Effect of irrigation water salinity and sodicity on soil tillage range, for the selected profiles, during the winter seasons,2008/2009.

Location	Type of irrigation water	Soil depth, cm	Liquid limit, %	Plastic limit, %	Plasticity range
1	Fresh water Meet Yazeed canal (control)	0-20	58.8	29.9	28.9
		20-40	56.6	28.5	28.1
		40-60	55.5	28.3	27.2
		60-80	55.6	27.2	28.4
		Mean	56.6	28.4	28.2
2	Drainage water with sewage wastes	0-20	56.5	28.2	28.3
		20-40	56.2	27.8	28.4
		40-60	55.6	27.5	28.1
		60-80	55.5	27.2	28.3
		Mean	56.0	27.6	28.3
3	Drainage water with sugar factory wastes(Hamdy drain)	0-20	55.8	28	27.8
		20-40	55.6	27.8	27.8
		40-60	54.9	27.5	27.4
		60-80	54.5	26.2	28.3
		Mean	55.2	27.3	27.8
4	Drainage water drain No. 6 (El Hamoul)	0-20	54.5	27.2	27.3
		20-40	53.8	26.5	27.3
		40-60	53.5	26.1	27.4
		60-80	53.2	25.8	27.4
		Mean	53.7	26.4	27.3

Table (2) :Effect of irrigation water salinity and sodicity, on soil tillage range, in the selected profiles during the summer seasons,2009/2010.

Location	Type of irrigation water	Soil depth, cm	Liquid limit, %	Plastic limit, %	Plasticity range
1	Fresh water Meet Yazeed canal (control)	0-20	62.0	30.2	31.8
		20-40	61.9	30.0	31.9
		40-60	61.5	29.8	31.7
		60-80	60.9	28.0	32.9
		Mean	61.6	29.5	32.07
2	Drainage water with sewage wastes	0-20	60.5	30	30.5
		20-40	60.1	29.8	30.3
		40-60	59.8	29.2	30.6
		60-80	59.5	28.9	30.6
		Mean	59.97	29.5	30.5
3	Drainage water with sugar factory wastes	0-20	55.8	27.9	27.9
		20-40	55.4	27.4	28.0
		40-60	55	27.2	27.8
		60-80	54.8	27.1	27.7
		Mean	55.3	27.4	27.8
4	Drainage water Drain No. 6 (El Hamoul)	0-20	56.8	28.5	28.3
		20-40	56.2	28.2	28.0
		40-60	55.9	27.8	28.1
		60-80	55.5	27.4	28.1
		Mean	56.1	27.9	28.1

In the winter season, Figs . 1,2 and 3,showed the effect of irrigation water with different levels of Ec and SAR values on soil liquid limit , plastic limit and plasticity index. As shown in Fig.1 , increasing Ec values in irrigation water (2,4,8 and 16 ds/m) with the same level of SAR 10 decreased soil liquid limit as (55.63,53.83, 54.64,and 50 %) respectively., with SAR 20,the liquid limit decreased with increasing salinity as follows(- 58.33, 59.33,58.06 and 53 %) respectively .With SAR 30 increased Ec values in irrigation water decreased soil liquid limit as follows(61.33,60.4,57.9 and 56.9 %)respectively. It was also noticed that ,increasing SAR values with the same level of Ec , the liquid limit was increased .The same trend was noticed with plasticity index as shown in Fig .3, increasing Ec values in irrigation water with the same level of SAR decreased the values of plasticity index .it was also noticed that , with increasing SAR values with the same values of Ec , the plasticity index increased .On the other hand the plastic limit values showed an opposite trend .as shown in Fig. 2 , increasing Ec values in irrigation water with the same level of SAR , increased the plastic limit . this may be due to the small amount of salts that introduced to soil in the winter season . Such quantity of salts did not adequate to affect soil consistency. It was also noticed that , with increasing SAR values in irrigation water with the same value of Ec , the plastic limit was increased .

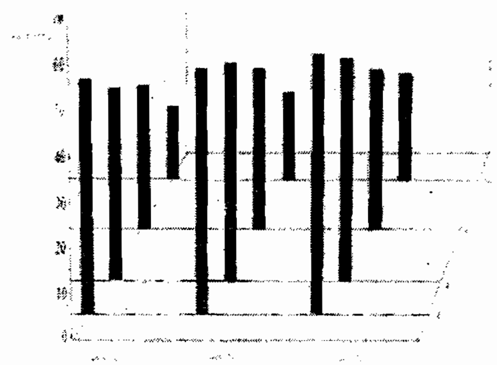
In the summer season ,data in Figs.4,5 and 6 , showed the effect of salinity and sodicity on soil tillage range (liquid limit , plastic limit and plasticity index) It was noticed that maize crop needed twelve irrigates with artificial salinization , consequently the salts which introduced to the soil in the summer season were adequate to affect on soil consistency , increasing salinity decreased soil liquid limit , plastic limit and plasticity index .but increasing sodicity increased (ALS) when Ec ,remained the same .

As shown in Fig. 4 , increasing Ec values in irrigation water (2,4,8 and 16 ds/m) decreased soil liquid limits as follows (61.03, 59.92, 58.10,and 52.90 %) respectively with SAR 10. It was also observed that , increasing SAR values with the same level of Ec , the liquid limit was increased .Data in Fig. 5, indicated that, increasing Ec values in irrigation water (2,4,8 and 16 ds/m)with the same level of SAR 10 ,decreased the plastic limit to (30.16 , 29.36, 28.8 and 26.1 %) respectively .the same trend was noticed with SAR 20 and SAR 30.

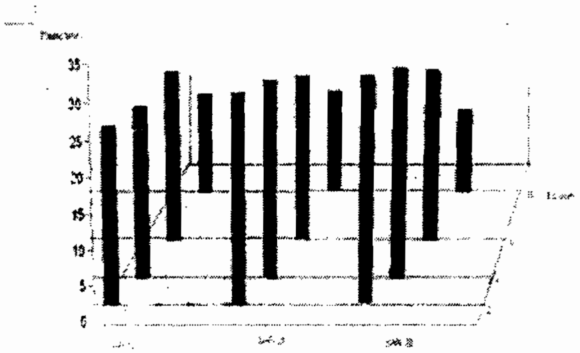
It was also noticed that , increasing SAR values with the same value of Ec , increased the plastic limit .These results are in harmony with those obtained by **Fabbri et al . (2003)** .They studied the effect of Nacl and $cacl_2$ concentrations on some mechanical properties of the clay soils . They found that increasing salinity decreased soil liquid limit and plastic limit . Also Fig 6 , showed that increasing Ec values in irrigation water (2,4,8 and 16 ds/m) with the same value of SAR 10 . decreased the plasticity index values as follows (30.86, 30.56, 29.3 and 26.73 %) respectively . The same trend was noticed with SAR 20 and SAR 30 . Also increasing SAR values with the same value of Ec , increased the plasticity index . These results are in agreement with those obtained by **Mishra et al . (2009)** . They evaluated the effect of the various concentrations of Nacl and $cacl_2$ on different soil – bentonite mixtures . They found that the liquid limit of the mixture decreased with increasing the salt concentrations .They also concluded that increasing SAR values in irrigation water led to increasing soil liquid limit, plastic limit and consequently plasticity index.

From abovementioned it could be deducted that except the plastic limit in the winter season , increasing salinity decreased atterburg limits (ALS) with the same level of SAR .This may be due to

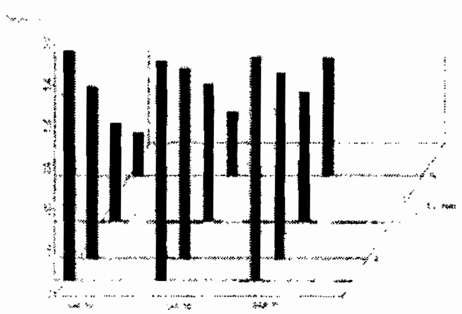
- Increasing salinity decreased the thickness of electrical double layer and zeta potential thus particles approached from each others, which agglutinated soil particles, then finally, decreased in values of soil liquid limit, plastic limit and plasticity index. **Sridharan et al (1986).**



fig(1) Effect of irrigation water quality on soil liquid limit during the winter season, 2008/2009.



fig(2) Effect of irrigation water quality on soil plastic limit during the winter season . 2008/2009.



fig(3) Effect of irrigation water quality on soil plasticity index during the winter season . 2008/2009.

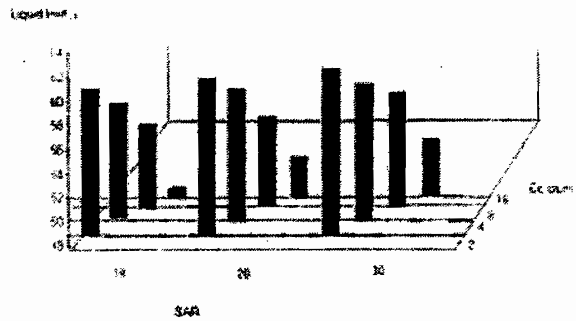


fig (4) Effect of irrigation water quality on soil liquid limit during the summer season,2009/2010.

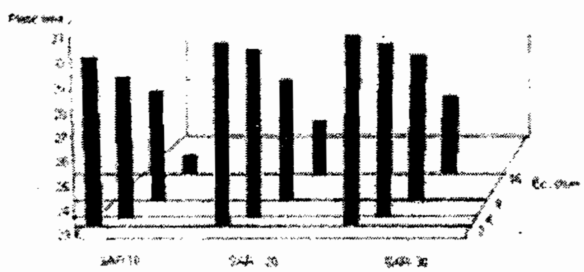
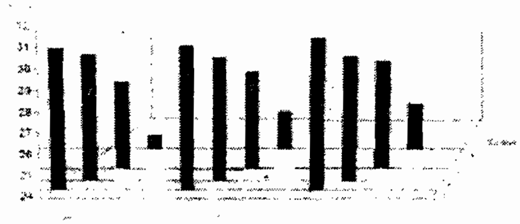


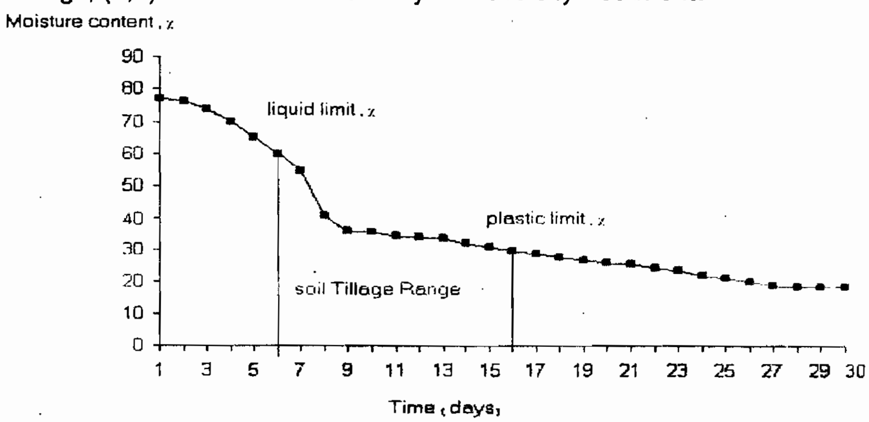
fig (5) Effect of irrigation water quality on soil plastic limit during the summer season,2009/2010



fig(6) Effect of irrigation water quality on soil plasticity index during the summer season , 2009/2010.

The suitable time for tillage:

Soils irrigated with different salinity and sodicity levels were subjected to intensive irrigation, and then moisture content of such soils was determined daily. curves expressing the relationship between time (in days) and moisture content of top soil were drawn . Thus moisture content at liquid limit and plastic limit were converted into time elapsed after irrigation , as farmers could till the soil at the optimum moisture content for good tilth, as shown in figs, (7,8)for the different salinity and sodicity treatments .



Fig(7): the suitable time for tillage after irrigation at Ec = 2 and SAR = 10

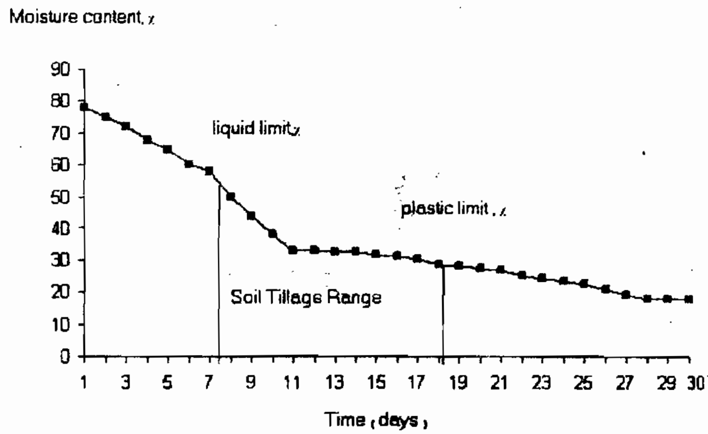
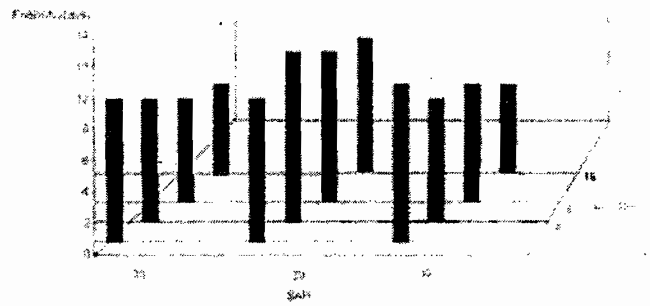


Fig (8) the suitable time for tillage after irrigation at Ec = 16 and SAR = 30.

Different consistency curves showed that suitable time for tillage of such salt affected clay soils must be after about 7 days , and no after about 17 days after irrigation , as shown, in table 3 , and fig 9.

Table (3): The suitable time (days) for tillage after irrigation at the different levels of salinity and sodicity.

Treatment		Days elapsed to achieve the liquid limit	Days elapsed to achieve the plastic limit	Friability Range
SAR	Ec ,ds/m			
10	2	6	16	10
	4	7	17	10
	8	8	18	10
	16	8	19	11
20	2	5	15	10
	4	6	19	13
	8	6	19	13
	16	6	20	14
30	2	5	16	11
	4	7	17	10
	8	6	17	11
	16	7	18	11



fig(9) Friability Range of the different levels of salinity and sodicity .

Soil shear strength:

Soil shear strength is the maximum resistance of a soil to shear stresses. Such value is very important in soil because it limits the shearing stress of plough and root to soil, which enable using the proper forces (plough) in plowing and choosing plant with suitable root system . As shown in Fig.10 the effect of different levels of Ec and SAR values ,in irrigation water, on soil shear strength after barley crop, in the winter season. Results showed that increasing SAR in irrigation water, under the same level of Ec value, increased soil shear strength. while increasing Ec values under the same level of SAR,decreased slightly the soil shear strength. The highest value of soil shear strength was 0.46 N/cm^2 with Ec value = 2 ds/m and SAR 30, and the lowest value was 0.29 N/cm^2 with Ec 16 ds/m and SAR 10. These results were similar to those obtained by **Kyei-Baffour *et al.* (2004)**. They found that the strength of the surface increases during salinization in response to increasing sodicity, it was also observed that these effects were not merely confined to the surface but existed through out the depth of the soil. The same results were obtained in Fig .11, in the summer season, after maize crop. Data showed that the highest value of soil shear strength was 1 N/cm^2 in case of Ec (2 ds/m) and SAR 20. while the lowest value was 0.66 N/cm^2 in case of Ec (16 ds/m) and SAR 10. Thus increasing sodicity and decreasing salinity increased soil shear strength , this may be due to the dispersion action of sodium in the soil and blocking soil pores by fine clay particles migration through out soil profile, and crust formation in response to low permeability.

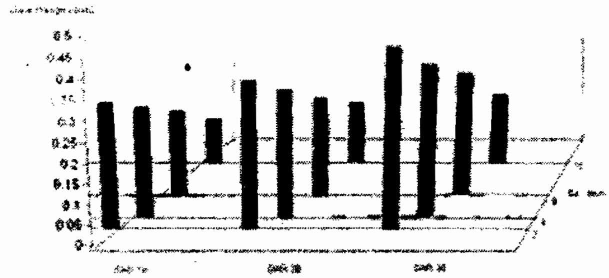


fig (10) Effect of irrigation water quality on soil shear strength during the winter season, 2008/2009.

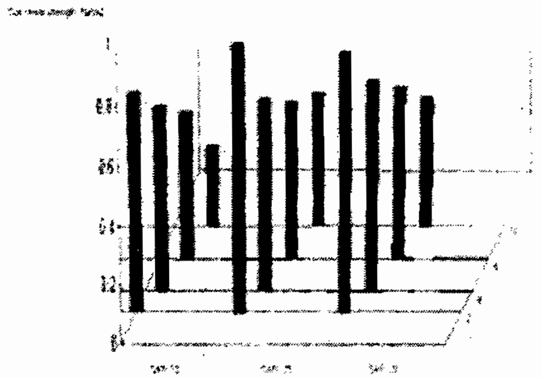


fig (11) Effect of irrigation water quality on soil shear strength during the summer season , 2009/2010.

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الملخص العربي

تأثير جودة مياه الري على حدود خدمة الاراضى وقوة القص لبعض الاراضى الطينية بشمال دلتا مصر

يؤدى نقص ومحدودية مياه الري العذبة في منطقة شمال الدلتا في مصر إلى تدهور خواص البناء الارضى ، وزيادة الصودية في مياه الري تؤدى إلى زيادة حد السيولة وحد البلاستيكية للتربة وزيادة الملوحة تؤدى إلى نقصها ومن هنا كان من الضروري دراسة تأثير هذه المياه ذات الجودة المنخفضة على حدود خدمة هذه الاراضى الطينية ،وبالتالي معرفة ميعاد إجراء عملية الخدمة .أيضا الجودة المنخفضة للمياه تؤثر على قوة القص للتربة ،فزيادة الصودية تؤدى إلى زيادة قوة القص والعكس صحيح فمع زيادة الملوحة تقل قوة القص . وهذا مؤشر إلى معرفة القوة اللازمة لحرث الأرض وخدمتها.

تم اختيار أربعة مواقع من الأرض والتي تروى بمياه صرف زراعي (مصرف نمره ٦) أو مياه صرف زراعي مع صرف صناعي بمخلفات مصنع السكر كما في حالة (مصرف حمدي العبد) بالحامول أو مياه صرف زراعي مع مياه صرف صحي (مصرف الغربية الرئيسي)، وأخيراً مياه عذبة من بحر ميت يزيد(الكنترول).

وكانت تجربة الليزمتيرات عبارة عن (٣٦)قطعة تجريبية في ثلاثة مكررات وأربعة معاملات للملوحة ٢، ٤، ٨، ١٦ ملليموز/ سم وكانت معاملات نسبة الصوديوم المد مص ١٠، ٢٠، ٣٠ مع ملاحظة تغيير الملوحة وتثبيت الصودية. واستخدام ملحي كلوريد الصوديوم وكلوريد الكالسيوم في التمليح الصناعي كمصدر للملوحة والصودية.

جمعت عينات المياه من المصادر المختلفة لمياه الري المتاحة شهرياً وتم تحليل عينات المياه كيميائياً لتقييم جودتها كمصدر للري .

أوضحت النتائج المتحصل عليها أن انسب مجال رطوبى يجب إجراء عمليات الخدمة فيه تحت ظروف التجربة هو ليس قبل مرور ٧ أيام وليس بعد ١٩ يوما من الري وفى هذه الفترة يكون المدى الرطوبى مناسب للحصول على أفضل ناتج حرث دون حدوث تدهور في الخواص الفيزيائية للتربة وبأقل طاقة ممكنة .