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PRELIMINARY GUIDELINE FOR YIELD RESPONSE TO SALINITY AND SODICITY OF IRRIGATION WATER

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ABSTRACT

The objective of this study was achieve preliminary Guideline of tolerance of barley, maize and wheat as a field crops and cucumber, pepper and tomato as vegetable crops to salinity and sodicity of irrigation water . Lysimeter experiments, using sand culture were curried out by cultivating field crops while plastic greenhouse was curried out using clay soil cultivated vegetable crops (cucumber, pepper and tomato). These crops were transplanted and irrigated by saline water with different EC_w values under two levels of SAR (7&14) for field crops and SAR7 for vegetable crops under North Delta climatic conditions. Linear equations of different crops indicated that, the relative yield decrease (%) with increasing unit of EC_w were 5.243 , 14.391, 8.187, 16.453 , 15.95 and 11.105 % for barley , wheat, maize, cucumber, pepper and tomato, respectively under SAR 7. Also, increasing the SAR of irrigation water to 14 increased the adverse effect of EC_w on the crop yields according to their tolerance to salinity of irrigation water. The crops under consideration could be arranged in the descending order,:- Barley >wheat > maize for field crops and tomato > pepper >cucumber for vegetable crops.

The multiple regression equations described the combined effect of EC_w and SAR_w on field crop yields were as follows: Yield decrement % = -14.238+5.243 ECw + 0.336 SARw (Barley), = 1.322 + 14.391ECw + 0.288 SARw (Maize) , and = -20.017 + 8.187ECw+ 0.528 SARw (Wheat). The simple regression for vegetable were as follows :

Yield decrement % = -12.192 + 16.453 ECw (Cucumber), =-10.779 + 15.952 ECw (Pepper),and = -9.688 + 11.105 ECw (Tomato)

Keywords , Guideline , Irrigation water , Salinity , Sodicity.

INTRODUCTION

Egypt is facing water shortage because of the population growth (2.7 % per year). The limitation of availability of fresh water, the degradation of water supplies and the growing demand on existence water to maximize the agriculture production compels the country to use all water sources i.e. drainage water, groundwater and treated wastewater (FAO 1973).

Farmers at the tail end of the irrigation canals unofficially reuse about 2 billion m^3 per year of drainage water directly for irrigation (El-Hessy and El-Kady, 1997). The use of low quality water over time has led to the following adverse effects :(i)degradation of soil properties and consequent reduction of agricultural production, and (ii) degradation of ground water quality, especially with traditional irrigation methods.

The plant growth rate decreases linearly as salinity increases above a critical threshold at which growth rate first begins to decrease (Mass and Hoffman 1977).Mass, (1986) tabulated a number of economic crops according to their tolerance to salt and stated that barley is tolerant, wheat is

moderately tolerant and maize is moderately sensitive as field crops , while cucumber ,pepper and tomato as vegetable crops are moderately sensitive

The salt tolerance of various crops are conventionally expressed (Mass and Hoffman, 1977) in terms of relative yield threshold salinity value (a) and percentage decrement value per ECw unit over the threshold (b), while soil salinity is expressed in terms of ECe in dS/m as the follows:

$$Y = 100\ b\ (ECe - a)$$

The use of saline water for irrigation should be evaluated for the specific conditions where it is used, since the crop yields depend on leaching fraction and climatic factors at the same locality. It was also found that, the model recommended for the relation between yield and soil salinity by Mass, does not fit well for yield and irrigation water salinity Abd El-Gawad and Ghaibeh, (1998).

Systematic approach was suggested by Abd El-Gawad and Ghaibeh (1977) to determine the relative yield as a result of increasing salinity of irrigation water. Therefore they considered the EC in Mass equation represents the mean electrical conductivity of the irrigation water throughout the season, and they suggested quadratic and exponential equations as follows:

$$Y = A + B\ (EC - T) + C\ (EC - T)^2 \text{ and}$$

$$Y = A \exp.\ (EC - T)$$

Where A = is the absolute yield, B= is the slope, EC= is the mean value of electrical conductivity of the irrigation water throughout the season, and T= salinity threshold expressed in dSm^{-1}.

Lack of farmer awareness about the use of drainage water for irrigation has led to health problems for farmers and farm animals as a result of pollutants and parasites in brackish water (DRI, 1995).

Given the above, it is clear that guidelines which used the brackish water for irrigation in Egypt is needed . The objective of this study ,therefore, was to evaluate the usability of low quality water with different levels of EC_w and SAR for irrigating six plant crops and to achieve a preliminary guideline of salt tolerance for these crops under local conditions.

MATERIALS AND METHODS

Two experiments were conducted at Sakha Agriculture Research Station .The first experiment was curried out in lysimeter using sand culture technique in three successive growing seasons started in winter season 2003 to study the effect of salinity and sodicity of irrigation water on the yield of barley (Hordeum vulgar L.), maize (Zea maus.L.) and wheat (Triticum aestivum L) crops as a field crops. These experiments were conducted in split plot design with four replicates . The salinity levels were assigned to the main plots, while the two levels of sodium adsorption ratio SAR 7 & 14 were devoted to the sup plots .The salinity levels expressed as electrical conductivity (EC_w) were: 2, 4, 8, 10, 12, and 16 dS/m for barley, 1, 1.5, 2, 3.5 and 5 dS/m for maize and 2.0, 4.0, 6.0, 8.0, 10.0 and 12.0 dS/m for wheat under SAR 7&14 as well as fresh water (0.5dS/m and 2.5 SAR) as a control .

The second experiment was carried out during winter season of 2003/2004 in lysimeter inside plastic green house using non saline clay soil irrigated with salinity water 1.5, 2.0, 2.5, 3.0 and 3.5 dS/ m under SAR7 for cucumber (Cucumis salivus L.), pepper (Capsicum annuum) and tomato (LY copersicon eaculentum M ill as a vegetable crops, as well as fresh water as a control .

Artificial salty solutions with different levels of EC and SAR were prepared using NaCl and $CaCl_2$ salts. Fresh water (tap water) was used for irrigation till complete germination .

All plots (1.92 m^2) were irrigated alternatively with the tested water and with half-strength nutrient solution of Hogland and Arnen (Hewitt,1966) to supply the plants with the essential macro and micro elements.

Total yields were expressed as g/plot or kg/plot and the data were statistically analyzed using SPSS program ver. 12.

RESULTS AND DISCUSSION

1- Effect of salinity and sodicity of irrigation water on yield:

The economic value of the crop is taken as a criterion when cultivated plants are compared together according to their tolerant to salt. Usually the relative yield of the crops irrigated with saline water is compared with that yield irrigated with fresh water (control). The salt level of soil which causing 50 % or 25 % yield depression are taken as the tolerable soil salt level for given crop, (FAO, 1973).

Data of absolute and relative yield of barley, maize ,wheat, cucumber, pepper and tomato as influenced by different levels of salinity and sodicity of irrigation water are listed in Tables (1 a&b). As a general trend, the yields of the different crops decreased as salinity increased under the two levels of water sodicity. The relative decrement in crop yields were differed from crop to another according to their tolerant to salinity and sodicity.

Table (1a) indicate that, barley is tolerant crop while, wheat is moderately tolerant ,whereas ,maize ,tomato, cucumber and pepper are moderately sensitive crops. These results are in a good agreement with those obtained by FAO,(1976), Mass (1986) and DRI (1993).

2- Mathematic Approach:-

The relative decrement of yield versus salinity and sodicity of irrigation water were evaluated through linear equation for each crop.

The relative yield decrement % represent dependant variable while the salinity expressed in EC dS/m represent the independent variable and the equation takes the form $y = ax + b$

where:- y = relative decrement %, x = salinity of irrigation water**.**
a = slope (yield reduction % due to increase EC_w by one unit)and
b = the intercept.

Different linear equations for the different crops indicate that, the relative yield decrements % with increasing one unit of EC_w, were 5.243 ,14.391 and 8.187 for barley, maize, and wheat as a field crops, respectively and 16.43 ,15.952 and 11.105% for cucumber, pepper and tomato as a

vegetable crops, respectively . Also, it worthy to observe that, with increasing SAR, the crop yield reduction % increase slightly with the same value of EC_w. This could be attributed to the specific effect of sodium and chloride ions toxicity (FAO, 1976). The crops under consideration, can be arranged in the following descending order, from salt tolerance.
Barley > wheat > maize for field crops and tomato > pepper > cucumber for vegetable crops

Table (1a): Yields of barley , maize and wheat field crops and values of the relative decrease(%) as affected by salinity and sodicity of irrigation water.

ECw (dS/m)	SAR 7		SAR 14	
	Yield (g/plot)	R.D (%)	Yield (g/plot)	R.D (%)
Barley				
0.5	360	-	359	-
2.0	358	0.58	356	0.88
4.0	345	4.19	340	5.33
8.0	270	25.02	265	26.22
10.0	233	35.30	224	37.63
12.0	176	51.12	161	55.17
16.0	87	75.84	60	83.29
Maize				
0.5	2710	-	2710	-
1.0	2530	6.64	1990	8.29
1.5	2400	11.11	1880	13.36
2.0	2210	18.12	1820	20.7
3.5	1660	38.5	1300	40.09
5.0	970	64.07	710	67.28
Wheat				
0.5	300.6	-	300.2	-
2.0	285.8	4..91	282.5	5.9
4.0	281.1	6.5	274.8	8.4
6.0	219.7	26.9	211.9	29.4
8.0	181.3	39.7	158.8	47.1
10.0	105.8	64.8	84.1	71.8
12.0	27.4	90.9	9.01	97.0

Table (1b): Yields of vegetable crops (kg/plot) and relative decrement as affected by salinity of irrigation water.

Crop / EC_w(dS / m)	Cucumber		Pepper		Tomato	
	Yield	R.D.%	Yield	R.D.%	Yield	R.D.%
0.5	5.94	-	11.19	-	6.89	-
1.5	5.38	9.43	10.18	9.03	6.56	4.79
2.0	4.90	17.51	8.5	20.02	6.20	10.01
2.5	4.35	26.77	7.88	29.6	5.83	15.38
3.0	3.59	39.56	6.82	39.05	5.37	22.06
3.5	3.12	47.47	6.15	45.00	4.52	34.4

3- Preliminary guideline for crop responese to salinity and sodicity of irrigation Water .

Data illustrated in Table (2) represent a guideline introduced from previous linear equations of crops which, include the expected yield reduction of and due to increasing irrigation water salinity under the two levels of SAR. Data indicate that each increase in irrigation water salinity will cause a proportionate decrease in the yield. Data also indicated that, barley crop is the most tolerant field crop followed by wheat, whlile maize was the least one. On the basis of, 50% reduction in crop yield, the crops can be arranged in the descending order from salt tolerant point of view, barley>wheat > maize for field crops and Tomato > Pepper = Cucumber for vegetable crops. Data also indicate that the bad effect of SAR on the yield was increased with increasing ECw of irrigation water and vice versa.

Comparing data presented in preliminary guideline (Table 2) with guideline introduced by FAO (1976) for different crops (Table 3) it could be found that values of EC_w causing reduction 50% of crop yield were 11.81 ,8.19 and 4.25 in the current Guideline while the corresponding values of FAO (1976) were 12,0 ,8.7 and 3.9 for barley, wheat, and maize, respectively.

Table (2): Yield decrement to be expected for some crops as a result of irrigation water salinity (FAO, 1976).

Crop	0%	10%	25%	50%	100%
Barley	5.3	6.7	8.7	12.0	19
Maize	1.1	1.7	2.5	3.9	6.7
Wheat	4.0	4.9	6.3	8.7	13
Cucumber	1.7	2.2	2.9	4.2	6.6
Pepper	1.0	1.5	2.2	3.4	5.8
Tomato	1.7	2.3	3.4	5.0	8.4

Table (3): Yield decrement to be expected for certain crops to salinity and sodicity of irrigation water.

Crop	10%*	25%	50%	75%	90%	100%
	SAR7					
	EC_w					
Barley	4.2	7.05	11.81	16.57	19.44	21.34
Maize	1.34	2.43	4.25	6.07	7.16	7.87
Wheat	3.1	5.0	8.19	11.37	13.28	14.55
Cucumber	1.35	2.26	3.78	5.30	6.21	6.82
Pepper	1.3	2.24	3.81	5.38	6.32	6.94
Tomato	1.8	3.12	5.37	7.6	8.98	9.88
SAR 14						
EC_w						
Barley	3.2	6.58	11.64	16.93	20.1	22.21
Maize	1.21	2.27	4.04	5.81	6.88	7.59
Wheat	2.89	4.64	7.59	10.52	12.28	13.46

*** The threshold values were taken at 10% yield decrease**.

The difference of values between the current guideline and FAO Guideline may be due to different climatic, conditions and to the soil salinity effect, which was taken into consideration by FAO, while the effect on crop yield in the present study was related to salinity of irrigation water only,since the crops were grown in sand culture.

4-The Combined Effect of EC_w and SAR_w:

The combined effect of salinity and sodicity of irrigation water on the relative yield decrement of each crop is described through the simple and multiple regression equations Table (4).

Table (4): Simple and multiple regression, model significance and correlation coefficient rating

Crop	Regression	Model significance	R	Rating	Slop*
Barley	Y= -10.54 + 4.577 EC + 0.471 SAR	*	0.98	T	4.57
Maize	Y= 1.322+ 14.391 EC_w + 0.288 SAR	*	0.97	M.S	14.39
Wheat	Y= -20.017 + 8.187 EC + 0.528 SAR	*	0.97	M.T	8.19
Cucumber	Y= -12.192 + 16.453 EC	*	0.985	M.S	16.45
Pepper	Y= -10.779 + 15.952 EC	*	0.99	M.S	15.59
Tomato	Y= -9.688 + 11.105 EC	*	0.915	M.S	11.1

T=tolerant MT= moderately tolerant MS== moderately sensitive

*** Crop reduction (%) / dS/m**

Data confirm the previous data where the barley is more salt tolerant crop followed by wheat is moderately tolerate crop followed by maize (moderately sensitive crops) .

The slope means that, the quantity of yield reduction due to one unit of ECw. where they recorded 4.58,8.18 and 14.39 for barley , wheat and maize ,respectively .Also ,it is worthy to mention that for vegetable crops, which take rating as moderately sensitive crops arranged in the following descending order according to their resistance to salinity of irrigation water : tomato > pepper > cucumber . The high values of slop may be due to the sensitive of these crops to salinity of irrigation water and to soil texture which tend to accumulate more salts along the growth season (FAO, 1976) . The crops under investigation lies between tolerant (barley), moderately tolerant (wheat) and the other lies in moderately sensitive rating . These results are in a good agreement with those recorded by (Mass,1986)

Using simple and multiple regression equations, the expected yield decrement % for different studied crops as affected by wide levels of both EC_w and SAR_w were calculated and presented in Table 5 & 6. It is clear that all models reveals significant this appear from correlation different.

Table (5): Combined effect of EC_w and SAR_w on expected relative yield decrease (%).

EC_w (dS/m)															
Barley															
SAR_w	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**
5	0	0	3.171	8.14	13.66	18.9	24.14	29.39	39.87	50.36	60.84	71.33	81.82	92.3	*
10	0	0	4.85	10.09	15.34	20.58	25.82	31.06	41.55	52.03	62.52	73.01	83.50	93.98	*
15	0	1.29	6.53	11.77	17.02	22.26	27.50	32.75	43.23	53.72	64.20	74.69	8.18	95.66	*
20	0	2.96	8.21	13.45	18.70	23.94	29.18	34.43	44.91	5.40	65.88	76.37	86.86	97.34	*
Maize															
SAR_w	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**
5	17.15	31.54	45.94	60.33	74.72	89.11	*	*	*	*	*	*	*	*	*
10	18.59	32.98	47.38	61.77	76.16	90.55	*	*	*	*	*	*	*	*	*
15	20.03	34.42	48.82	63.60	77.60	91.99	*	*	*	*	*	*	*	*	*
20	21.47	35.86	50.26	64.65	79.04	93.43	*	*	*	*	*	*	*	*	*
Wheat															
SAR_w	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**
5	0	0	7.18	15.37	23.56	31.75	39.93	48.12	64.49	80.87	*	*	*	*	*
10	0	1.63	9.82	18.01	26.20	34.36	42.57	50.76	67.13	83.51	99.88	*	*	*	*
15	0	4.28	12.46	20.65	28.84	37.03	45.21	35.40	69.77	86.15	*	*	*	*	*
20	0	6.92	15.10	23.29	31.48	39.67	47.85	56.04	72.41	88.79	*	*	*	*	*

Table (6): The effect of EC_w on relative yield decrease (%) atSAR=7

Crop	**Cucumber**	**Pepper**	**Tomato**
EC_w (dS/m)	**SAR = 7**		
1	4.261	5.173	1.417
2	20.714	21.125	12.522
3	37.167	37.077	23.627
4	53.62	53.029	34.732
5	70.073	68.981	45.837
6	86.526	84.933	56.942
7	-	-	68.047
8	-	-	79.152
9	-	-	90.257

5- Crop yield decrement according to Richard classes (1954).

Multiple regression equation for field crop was used to evaluate the different classes suggested by Richard(1954) for evaluating water quality and its suitability for irrigation under North Delta conditions. Data for every crop under different classes in sandy soil were calculated and presented in Table (7). The data in Table (7) evidently proved that all water salinity and sodicity levels used under sandy culture are suitable for barley crop if 15-20 % yield is supposed to be an acceptable decrement level.

Table (7): Field crop yield decrement (%) to be expected due to use of Richard's classes for irrigation water under North Delta conditions.

Class	Barley	Maize	Wheat
C_1-S_1	0-0	5.6-7.8	0-0
C_2-S_1	0-0	7.8-15.0	0-0
C_3-S_1	0-0.92	15.0-36.58	0-3.68
C_4-S_1	0.92-15.34	36.58-76.16	3.68-26.2
C_1-S_1	0-0	7.95-10.10	0-0
C_2-S_2	0-0	10.10-17.3	0-0
C_3-S_2	0-3.61	17.3-38.89	0-7.91
C_4-S_2	3.61-18.03	38.89-78.46	7.91-30.42
C_1-S_3	0-0	10.25-12.41	0-0
C_2-S_3	0-0	12.41-19.6	0-0
C_3-S_3	0-6.29	19.6-41.19	0-12.13
C_4-S_3	6.29-20.71	41.19-80.77	12.13-34.65

Barley crop seems to be tolerant to salinity and sodicity than wheat but maize is less tolerate. So, all salinity levels with low sodicity (S_1) are suitable for barley according to this proposition. Whereas, wheat crop seems to be moderately tolerant, which recorded yield decrement by about 43.655% in the higher level of salinity and sodicity (C4 and S3)

Maize crop consider moderately sensitive which shows crop reduction at all level of irrigation water salinity and sodicity. According to Richard (1954) classes the studied field crops can be arranged in the following descending order : Barley > Wheat > Maize .

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أدلة أولية لاستجابة المحصول لملوحة وقلوية مياه الري

محمد مصطفي رجب

معهد بحوث تحسين وصيانة الأراضي والمياه والبيئة

☒ تم عمل دليل أولى لمقاومة المحاصيل لملوحة الأرض وقلوية مياه الرى على محاصيل الشعير والذرة والقمح كمحاصيل حقلية وبعض الخضر مثل الخيار والطماطم والفلفل .

☒ وقد أجريت تجربة فى أحواض أسمنتية فى مزرعة رملية للمحاصيل الحقلية بينما استخدمت الصوب البلاستيكية (أرض طينية) لمحاصيل الخضر والتى رويت بماء مالح مختلف فى قيم ..

☒ التوصيل الكهربى تحت مستويين معامل ادمصاص الصوديوم (SAR_7 & SAR_{14}) .

وقد أظهرت النتائج بالاستعانة بالمعاملات الخطية لمختلف المحاصيل أن النقص النسبى لكل وحدة ملوحة كانت 5,243 ,1491 , 187, 8 , 453, 16 , 95, 15 , 205, 11 للشعير والقمح والذرة والخيار والفلفل والطماطم على التوالى تحت معامل المصاص الصوديوم 7 .

وأن زيادة معامل المصاص الصوديوم لمياة الرى زاد من التأثير الضار لملوحة مياة الري على المحصول تبعا لتحمل تلك المحاصيل لملوحة مياة الرى .

وعلى ذلك يمكن ترتيب المحاصيل تحت الدراسة حسب مقاومتها للملوحة كالآتي :-

- الشعير > القمح > الذرة للمحاصيل الحقلية والطماطم > الفلفل > والخيار لمحاصيل الخضر.

كما أن معادلات الانحدار للمحاصيل الحقلية كانت كالآتي :-

النقص النسبى لمحصول الشعير = - 238, 14 + 234, 5 EC_W + 336, 0 SAR_W .

النقص النسبى لمحصول الذرة = 322, 1 + 391, 14 EC_W + 288, 0 SAR_W .

النقص النسبى لمحصول القمح = - 017, 20 + 187, 8 EC_W + 528, 0 SAR_W .

النقص النسبى لمحصول الخيار = - 192, 12 + 453, 16 EC_W .

النقص النسبى لمحصول الفلفل = - 779 , 10 + 952, 15 EC_W .

النقص النسبى لمحصول الطماطم = - 688, 9 + 105, 11 EC_W .