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Potential of using drainage water for wheat production in Iraq

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Abstract: A biological experiment was carried out to quantify the effects of drainage water on yield, yield components and ions uptake of wheat. Results showed that yield components viz, tiller and spike no., weight of seed, protein yield, and total yield potential significantly depressed as salinity (ECiw) of irrigation water increased. The 90, 75 and 50% yield potential at irrigation with ECiw's were 4.4, 6.5, and 10.0 dSm-1. The results revealed also that ion uptake (N, P and K) was linearly reduced ($r = 0.999$), in contrast, Na was linearly ($r = 0.977$) increased, whereas Ca and Mg curvilinearrly were depressed ($R = 0.926$ and 0.900) as ECiw of irrigation water increased. The results confirmed that drainage water with salinity level up to 4 dSm-1 with leaching fraction (LF) more than 15% can safely be used for irrigation of wheat crop grown in medium textured soil (Clay loam) under efficient drainage system and suitable agricultural practices.

Key words: Saline water, drainage water, yield, ion uptake.

إمكانية استخدام مياه الصرف لإنتاج القمح في العراق

جواد كاظم العكيلي

ملخص: أجريت تجربة بيولوجية لتقييم تأثير استخدام مياه الصرف علي مكونات وحاصل وامتصاص العناصر الغذائية لنبات القمح . وقد أشارت النتائج إلى أن مكونات الحاصل : عدد كل من التفرعات والسنابل ووزن 100 بذرة وحاصل البروتين والحاصل الكلي انخفضت إحصائيا نتيجة زيادة ملوحة ماء الري المستخدم في هذه الدراسة، فقد انخفض مستوى الإنتاجية إلى 90 ، 75 و 50% من الحاصل الكلي عند مستويات ملوحة ماء ري 4.4 ، 6.5 ، 10.0 ديسي سيمينز م-1 . كما دلت النتائج علي أن امتصاص العناصر الغذائية N و P و K انخفض خطيا (r > 0.999) بينما زاد امتصاص كل من Ca و Mg بشكل منحنى خطي (معادلة من الدرجة الثانية) (R = 0.962 , 0.900) . وعلى خلاف ذلك زاد امتصاص أيون الصوديوم خطيا نتيجة زيادة مستوى ملوحة ماء الري (r = 0.97**). وقد أكدت النتائج علي إمكانية استخدام مياه الصرف ذات ملوحة 4 ديسي سيمينز م-1 مع معامل غسل اكبر من 15% بكفاءة في ري نبات القمح النامي في الترب المتوسطة القوام عند وجود نظام صرف كفء ومع مراعاة استخدام الوسائل التطبيقية والإدارة الملائمة.

كلمات مفتاحية : مياه مالحة ، مياه صرف ، إنتاج ، قمح ، الأيونات .

Introduction

Water is a limiting factor for extended and intensive agricultural production. Because of scarcity of surface water, the use of drainage water will became a more useful strategy in the future for completmental and/or supplemental irrigation in semi-arid and arid regions (Bernstein *et al*., 1973; Maas, 1985; Sharma *et al*., 1990; Rhoades *et al*., 1992). In Iraq, drainage water of Mesopotamia valley contains appreciable amounts of salt ranging from 5.1 to 33.1 gL^{-1} (8 – 52 dSm^{-1}). The chemical composition of drainage water is primarily depending on the location, temperature and season, with Na^{+}, Ca^{2+} and Mg^{2+} ions are predominant (Hanna, 1983). Many reports have mentioned the effects of artificial saline ground water on various economic crops (Ayers & Westcott, 1976; Soliman, 1978; Maas, 1985; Rabie *et al*., 1985; Gupta & Yadav, 1986; Bauder *et al*., 1992; Alsaadawi & Dahash , 2000). The critical limits saline of water which caused 50% wheat yield reduction in loamy sand and clay soils were 13.6 and 7.5 dSm^{-1} respectively (Gupta & Yadav, 1986).

The information about using saline water for irrigation of cereal crops is still limited. Therefore, the aim of this work was to justify the effect of saline drainage water on yield potential, yield components and ions uptake of wheat in addition to its effect on soil salinity build up on medium textured soil.

Materials and Methods

An experiment was conducted at Twithia site Agric. & Biol. Center Baghdad, using drainage water and leaching fraction for irrigation wheat crop (*Triticum aestivum* L.) cv. Maxipak under lath house conditions.

Ten seeds were grown in pots containing 800 g. gravel, 500 g sand, and 5 kg air dried soil. Surface soil sample (0 – 30 cm) from Rashidia site, Baghdad Governorate was dried and ground to pass through 2 mm sieve. The soil was clay loam (214 g sand, 420 g silt, and 366 g clay kg^{-1}) in texture with pHe (paste) 7.6, EC_e 1.7 dSm^{-1} , OM 20.3 g kg^{-1}, lime 336 g kg^{-1}, soluble Na, Ca, and Mg 7.1, 4.5 and 2.5 mML^{-1}, sodium adsorption ratio (SAR) 2.7, and $NaHCO_3$-P 7.1 mg kg^{-1} . The irrigation water treatments consisted of eight salinity levels (2 – 12 dSm^{-1}) and canal water was used as control treatment with the salinity (1 dSm^{-1}) with nine leaching fractions ranging from 2.5 to 30% (Table 1).

After emergence, the plants were thinned to 5 plants per pot. Three equal split amounts (33, 20, and 25 mg kg^{-1} soil) of the major nutrients (N, P and K) were applied at 0 , 30 and 60 days from sowing date. At maturity stage, the plants were harvested, dried at 65 °C for 48 h, then straw and seed weight recorded. Total N was determined by Kjeldahl method (Black, 1965). Protein yield (Py) was calculated according to the following equation :

$$Py = \%\ Seed - N \times 5.70 \times Seed\ yield.$$

The mineral plant composition (i.e, P, K, Ca and Na) was estimated according to standard procedures outlined by Chapman & Pratt, 1961. Soil core composite samples during and after the growing season were analyzed for EC_e and SAR in each pot.

Statistical analysis

The randomized complete block design with six replicates was used in this work. Each block contained nine salinity treatments. The analysis of variance (ANOVA) and simple linear and nonlinear regressions were applied to the data according to Steel & Torrie (1980).

Table 1. The chemical composition of irrigation water (iw) and leaching fraction (LF%)used.

Treatment EC_{iw} (dSm^{-1})	Cationic concentration (mML^{-1})			SAR	LF (%)
	Na	Ca	Mg		
1	3.8	1.4	2.7	1.9	2.5
2	7.3	2.7	4.2	2.8	5.0
3	14.6	4.6	5.6	4.6	7.5
4	19.3	5.3	7.5	5.4	10.0
5	28.5	5.4	11.1	7.0	12.5
6	34.1	6.8	14.0	7.5	15.0
8	44.5	7.6	17.0	9.0	20.0
10	53.4	8.1	18.7	10.3	25.0
12	64.0	9.0	20.7	11.7	30.0

* Control treatment (canal water).

Results and Discussion

Yield potential

Using EC_{iw} drainage water with increasing salinity (EC_{iw}) level above 2 dSm^{-1} significantly reduced straw and seed yields, and yield potential (total above ground dry matter production) (straw plus seed) of wheat (Table 2). Irrigation water with salinity of 2 and 3 dSm^{-1} gave significantly high yield potential as compared with canal water as control treatment (1 dSm^{-1}). This phenomenon might be due to the fact that drainage water may contain more nutrients (i.e., Ca and Mg) than canal water (Table 1). Increasing the EC_{iw} level from 3 to 12 dSm^{-1} drastically depressed the straw seed and yield potential by 100, 73 and 66% of control (1 dSm^{-1}) respectively. The yield potential (YP) was linearly decreased by 1.80 g pot^{-1} for each 1.0 dSm^{-1} according to the least squares analysis (YP = 30.76 – 1.80 EC_{iw}) (r = 0.970** at $p < 0.01$ level) (Fig. 1). The effects of drainage water on yield components might be attributed to low water availability and / or osmotic inhibitory effect, specific ion toxicity, and/ or low growth rate and low net assimilation (Wicnarajaah, 1990; Bauder *et al*., 1992). These findings are in agreement with results reported by other workers (Soliman *et al*., 1978; Mashhady *et al*., 1982; Maas, 1985 ; Abdul-Halim *et al*., 1988).

The relative yield potential at any given soil salinity level (EC_e) and water salinity (EC_{iw}) at maturity stage were calculated. The following linear model

$$Y / Y\ max = Yr = 1- b\ (EC_e – a),$$

where y = yield, y max = yield of non saline control, a = Salinity threshold, and b = Slope (regression coefficient). The linear model fits the relationship between yield potential and soil salinity very nicely as judged by the high coefficient of determination (r^2) and the low standard error of estimate (SE.e). These observations are in line with the results found by others (Maas & Hoffman, 1977; Rhoades *et al*., 1992).

The relative wheat yield (Yr) was linearly related to soil salinity (EC_e) as follows: Yr = 100- 5.9 (EC_e – 5.6) ; (r^2 = 0.920**, and SE.e = 8.6%)

This equation shows that yield potential is significantly reduced by 5.9% for each 1.0 dSm^{-1} soil salinity. The relative 90, 75 and 50% yield potential at irrigation water salinity (EC_{IW}) levels with respectively 4.4, 6.5 , and 10.0 dSm^{-1} and soil salinity (EC_e) levels of 7.3, 9.8, and 14.0 dSm^{-1}, respectively are shown in Table 3. Generally the result are in agreement with other results as confirmed by Maas & Hoffman, 1977 ; Maas, 1985.

Table 2. Yields and yield components of wheat as a function of drainage water.

Treatment EC_{IW} (dSm^{-1})	Straw yield	Seed yield	Yield potential (Total biomass)	Wt. Of 100 seed	Protein grain yield	Tiller no.	Spike no.
	g pot^{-1}			g	mg pot^{-1}	$Plant^{-1}$	
1	17.48	7.87	25.35	2.67	975.1	3.0	2.1
2	19.19	9.31	28.50	2.88	1230.0	3.0	2.2
3	18.34	8.73	27.17	2.73	1141.5	3.0	2.1
4	16.60	7.63	24.23	2.52	1046.1	2.7	2.0
5	15.19	6.70	21.89	2.47	918.1	2.7	1.7
6	14.18	6.04	20.22	2.38	866.3	2.7	1.7
8	11.73	5.81	17.54	2.35	844.9	2.0	1.4
10	7.99	3.39	11.38	2.00	581.3	1.0	1.0
12	6.94	1.75	8.69	1.75	325.0	1.0	1.0
LSD*	1.34	0.71	2.02	0.11	96.9	0.8	0.5

* Least significant difference at 0.05 level.

Table 3. Yield potential (straw + seed) of wheat as related to irrigation water salinity (EC_{iw}) or soil salinity (EC_e).

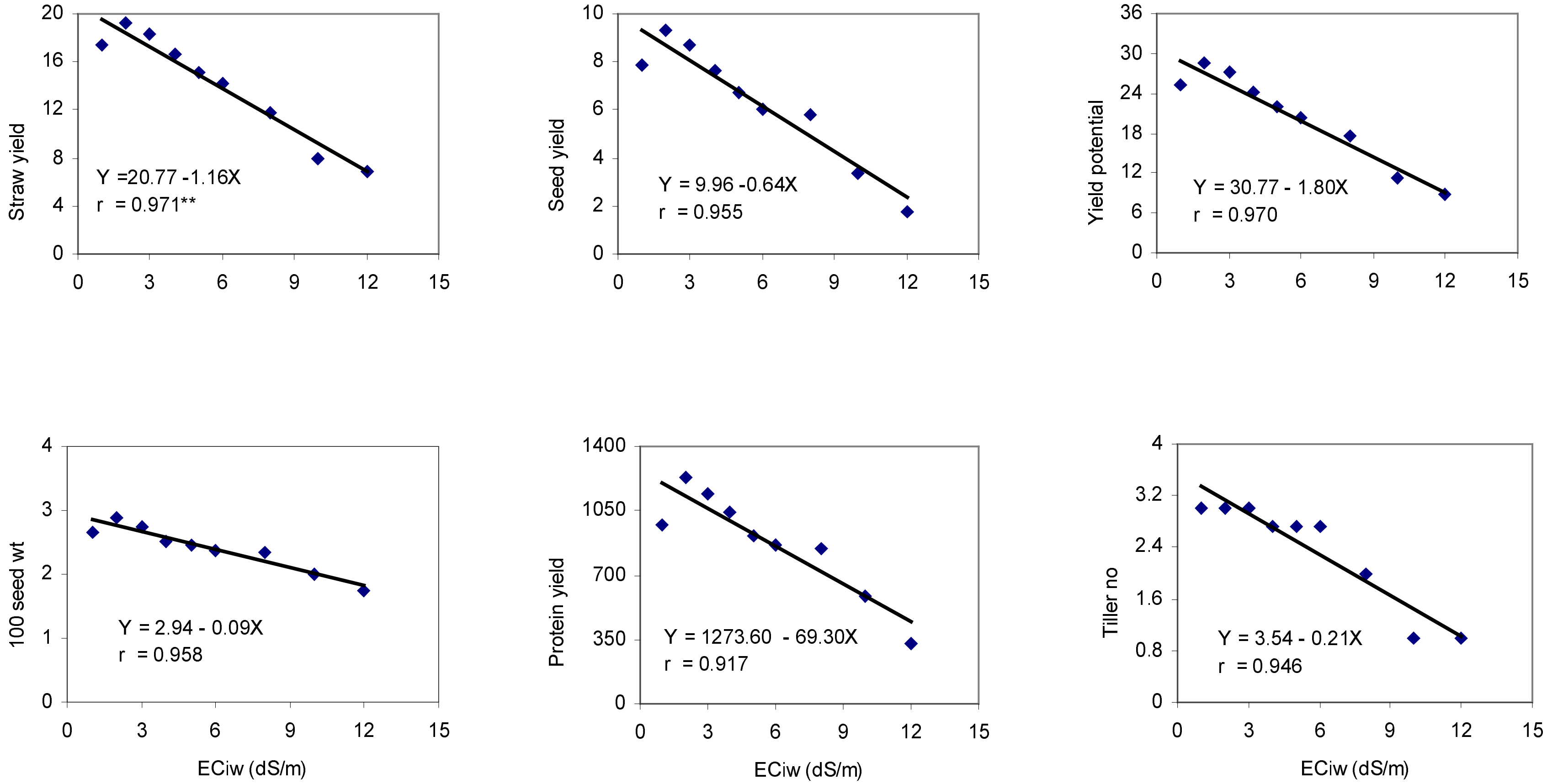
Yield potential (%)											
100		90		75		50		25		0	
EC_{iw}	EC_e	**EC_{iw}**	EC_e	**EC_{iw}**	EC_e	**EC_{iw}**	EC_e	**EC_{iw}**	EC_e	**EC_{iw}**	EC_e
3.0	5.6	4.4	7.6	6.5	9.8	10.0	14.0	13.6	18.3	17.0	22.5

Yield components

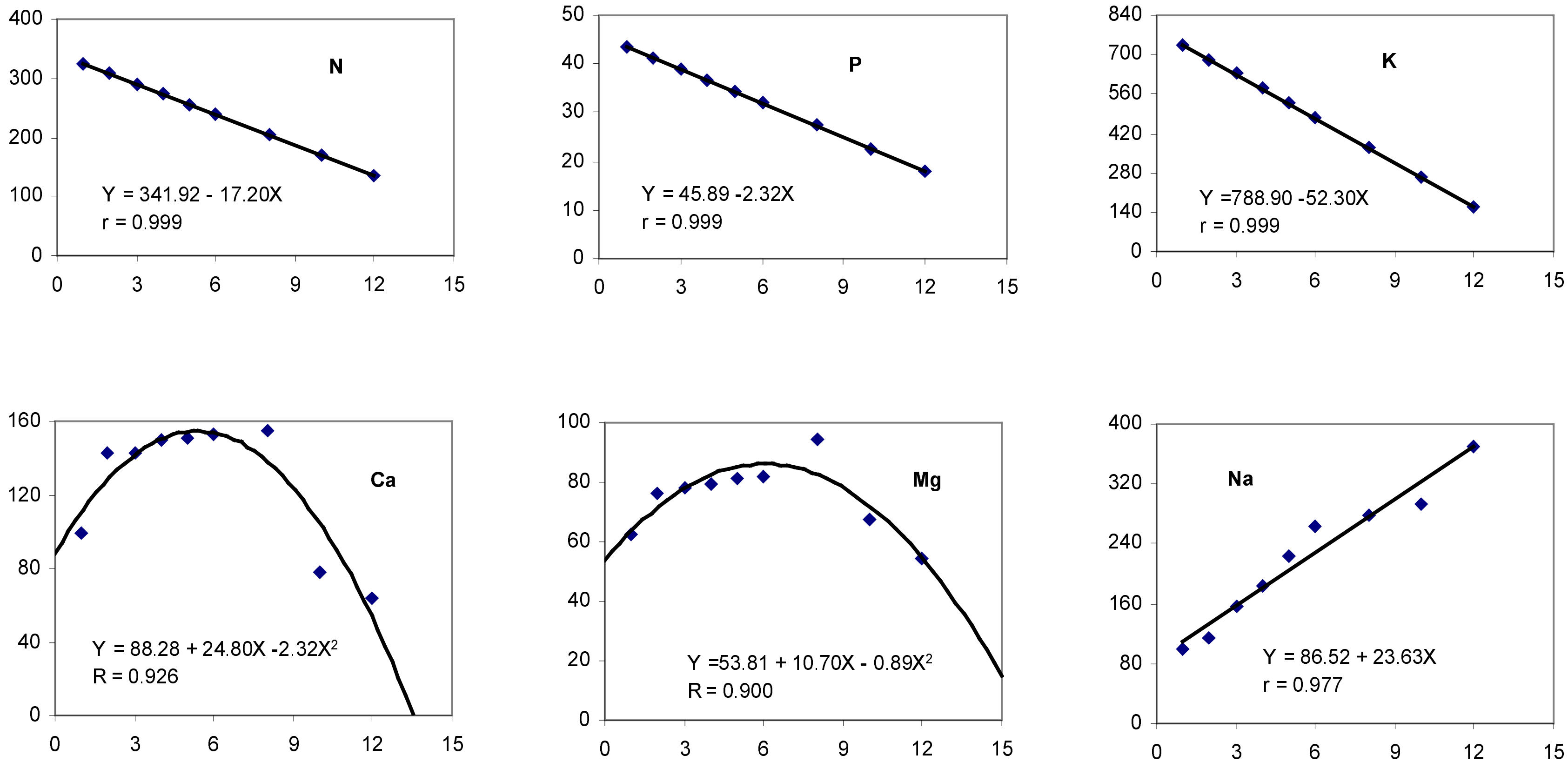
Tiller no., and spike no. per plant, weight of 100 seeds and protein yield were considered as criteria for yield components. In general, increasing salinity levels of EC_{iw} from 1 up to 12 dSm^{-1} statistically decreased those parameters by 67, 50, 35 and 66% respectively (Table 2). Also the linear regression results (Fig 1) showd highly significant decreasing rate as 1.05, 0.62, 0.09, and 69.30 in all yield components (viz tiller and spike no. s $plant^{-1}$, weight of 100 seed (g), and protein yield (mg pot^{-1} with highly significant correlation coefficient (r > 0.917**) as irrigation salinity increased by 1.0 dSm^{-1} , respectively. This is in agreement with previous studies (Abdel-Halim *et al.*, 1976 ; Abdul-Halim *et al.*, 1988) who found that yield component significantly declined as salinity level increased.

Ion uptake

The results indicated that drainage water had pronounced effects on ions uptake (i. e, N, P, K, Ca, Mg, and Na). For example, increasing EC_{iw} level of irrigation water applied from 1 up to 12dSm^{-1} gradually depressed N, P and K uptake by 58, 59 and 78% . The absorption pattern of those nutrients followed a linear trend with high reductive rate (17.20, 2.32 and 52.30 mg pot^{-1} per 1 dSm^{-1}), and with high correlation coefficient (r = 0.999**) (Fig. 2). On the other hand, the uptake of secondary nutrients such as Ca and Mg was directly increased as a parabolic trend upto certain level of ECiw and then sharply declined. The ECiw's maximum of uptake of Ca, and Mg were 5.4 and 6.0 dSm^{-1}, respectively, according to the quadratic model (Fig. 2). In contrast, Na uptake was significantly increased by using the drainage water. So, using 12 dSm^{-1} level of irrigation, water Na uptake increased by 2.7 folds as compared with control (canal water, 1 dSm^{-1}). The Na uptake followed a linear model with high enhansive rate of 23.63 mg pot^{-1} per 1 dSm^{-1} with high r value (0.977**). The synergistic effect of drainage waters on Na uptake might be explained due to their chemical composition, especially they had high measurable amount of Na in comparison to other measured cations (Ca & Mg) (Table 1).



** All correlation coefficients (r) are significant at 0.01 level
Figure 1. Effect of drainage water on yield components of wheat



** All correlation coefficients (r) are significant at 0.01 level
Figure 2. Influence of drainage water on ion uptake of wheat (mg/pot.)

Table 4. Chemical composition of soil solution and soil salinity during growing season of wheat crop

Treatment EC_{iw} (dSm^{-1})	Cationic concentration (mML^{-1}) Na	Ca	Mg	SAR	ECe dSm^{-1}
1	5.1	1.6	3.7	2.2	2.6
2	10.9	3.6	6.8	3.4	4.4
3	27.0	9.4	12.7	5.7	6.0
4	46.2	12.5	14.1	9.0	7.2
5	53.2	13.7	16.0	9.8	8.0
6	59.2	13.8	16.9	10.7	10.2
8	68.5	13.9	19.5	11.9	12.0
10	76.5	14.0	21.7	12.8	14.0
12	90.4	14.6	28.3	13.8	15.5
$LSD_{0.05}$					1.5

Soil salinity and soil SAR buildup

Soil salinity (EC_e) gradually increased with increasing salinity level of drainage water used (EC_{iw}) (Table 4). The results of least squares analysis showed that soil EC_e (y) build up was increasing EC_{iw} (X) according to the best linear equation =

$$Y = 2.25 + 1.18 X$$

with high r value (0.992) and low standard error of estimate, SE.e (0.60). So, soil EC_e incensed by constant rate of 1.18 dSm^{-1} for each 1 dSm^{-1} of EC_{iw}. Meanwhile, soil SAR also increased due to the use of drainage water. The linear equation revealed that the soil SAR (y) was related to the SARiw (X) as follows:

($Y = 0.68 + 1.22x$) with high r and low SE.e (0.974** and 1.01)

The result confirmed that EC_e and SAR of the soil used as growing media increased with use of drainage water for irrigation. Similar results reported by others (Sharmn *et al*., 1990 and Rhoades *et al*., 1992 ; Fahad, 2000) found that, in general, both criteria of soil considerably increased with using saline waters for irrigation of cereal crops.

Conclusion

From the obtained data, we conclude that using drainage water upto 4 dSm^{-1} with leaching fraction (LF) more than 15% can be safely used for production of wheat under medium growing culture (Clay loam soil) with efficient drainage system and suitable agricultural practices.

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