The Role of Soil and Water Salinity Management on Quinoa Crop Productivity

Oula Noori Ebrahim Khaldoun Ibrahim Abbas* Ibrahim Abbas Dawood
Ahmed Hatif Salim
National Center for Water Resources Management – Ministry of Water Resources – Baghdad
*Corresponding author's email: khaldoun.ibrahim1203a@coagri.uobaghdad.edu.iq

Abstract

A field experiment was carried out using the seeds of the quinoa crop for winter season 2020-2021 in the experimental field of Al-Raed Research Station, which is located 20 km west of Baghdad. The experiment was designed according to the Completely Randomize Blocks Design (CRBD), as the field was divided into nine blocks (Experimental board) with dimensions of (8×5) meters representing three different treatments (T1 saline well water, T2 mixed salty and fresh water, T3 fresh river water) and with three replications for each treatment. The soil salinity values were high just before planting until reach the flowering stage and then soil salinity decreased during the rest of the season and recorded 11.2 $dS.m^{-1}$ in the surface layer when irrigated with mixed water, and reached 6.1 $dS.m^{-1}$ in the surface layer when irrigated with fresh water. The productivity values of this study was showed that the irrigation treatment with fresh water had the highest productivity values and recorded 935 kg/ha, while lowest value of productivity was recorded 595 kg/ha with saline water treatment. The results of the statistical analysis using the SPSS program indicated that there were significant differences in the productivity values.

Keywords: Quinoa, Saline water, Irrigation management, Crop productivity

دور أدارة الترب المالحة والمياه المالحة في أنتاجية محصول الكينوا

علا نوري إبراهيم   خلدون إبراهيم عباس *   إبراهيم عباس داود
احمد هاتف سالم
المركز الوطني لادارة الموارد المائية – وزارة الموارد المائية – بغداد
*المؤلف المراسل: khaldoun.ibrahim1203a@coagri.uobaghdad.edu.iq

المستخلص

نفذت تجربة حقلية بأستخدام بذور محصول الكينوا للموسم الشتوي 2020 - 2021 في حقل تجارب محطة أبحاث الرائد والتي تقع على بعد 20 كم غرب بغداد ، تم تصميم التجربة وفق تصميم القطاعات الكاملة التعشية Completely Randomize Blocks Design (CRBD) إذ تم تقسيم الحقل إلى 9 قطع (لوح تجريبي) ذات أبعاد (8×5) متر تمثل ثلاثة معاملات مختلفة وهي (T1 مياه بئر مالحة ، T2 مياه مختلطة مالحة وعذبة ، T3 ، مياه نهر عذبة) وبثلاثة مكررات لكل معاملة ، كانت قيم ملوحة التربة عالية قبل الزراعة وصولا الى مرحلة التزهير وأنخفضت ملوحة التربة بشكل كبير في نهاية الموسم إذ وصلت إلى $11.2\ dS.m^{-1}$ في الطبقة السطحية عند السقي بمياه مخلوطة ، ووصلت إلى $6.1\ dS.m^{-1}$ في الطبقة السطحية عند السقي بمياه عذبة. سجلت أعلى قيم للإنتاجية في معاملة الري بالمياه العذبة إذ وصلت قيمة الانتاجية إلى 935 كغم/هكتار وأقل قيمة كانت 595 كغم/ هكتار في معاملة الري بالمياه المالحة ، أشارت نتائج التحليل الأحصائي بأستخدام برنامج SPSS إلى وجود فروقات معنوية في قيم الأنتاجية.

الكلمات المفتاحية: الكينوا، الماء المالح، ادارة الري، انتاجية المحصول

1. Introduction

Agriculture plays a major role in economic and social development in many countries in the world, especially in developing countries, most of which is located in dry, arid and semi-arid regions.

The problem of salinity has become one of the main problems facing the Iraqi agricultural sector, and most of the lands of central and southern Iraq are suffered from different degrees of salinity, and the demand of water will increase and led to more competition in difference sectors that cannot be met in the future (Ewaid, et al., 2019)

The treatment of the problem of soil salinity is mainly done through the reclamation of saline soils, but in the event that it is not possible to implement reclamation projects in certain periods, management methods must be taken for saline soils, One of the best ways to manage saline soils is the cultivation of saline-tolerant crops Agricultural crops suitable for each level of high salinity (Huang et al., 2019) Many countries in the world have tended to use non-traditional water resources in agriculture and other human activities to tackle the challenge of scarcity of fresh water, which has become a natural phenomenon in many countries of the world. Recently, there has been a tendency to use saline water as an alternative to filling part of the water needed in agriculture, taking into account the appropriate field management for this use (Adolf et al., 2013), (Gertsis and Zoukidis, 2017).

The use of saline water in the cultivation of salt-tolerant crops helps to preserve water resources from depletion and helps to sustain agricultural production, taking into account the use of appropriate management methods for soil and water salinity and reducing the negative effects on soil characteristics. (Aswad, 2011) explained that the cultivation of salt-tolerant plants that produce vegetative cover that absorbs salts and store it in its biomass. Quinoa is a multi-purpose crop grown mainly for its gluten-freeness and for obtaining its seeds of high nutritional value and rich in protein, essential elements, fiber and unsaturated fats. Quinoa tolerates various environmental conditions such as dryness and salinity of the soil (Angeli ,et al., 2020), (Turcios, et al., 2021), (Hu ,et al., 2022).

The quinoa crop is an annual and self-pollinating herbaceous plant. The Andes Mountains of South America are the original home of quinoa, which has been cultivated for more than 5,000 years in the area around Lake Titicaca in Peru, Bolivia and Chile (Jacobsen et al., 2003), (FAO, 2016).

2. Materials and Methods

A field experiment was carried out using the seeds of the quinoa crop for the winter season 2020-2021 in the experimental field of Al-Raed Research Station, which is located 20 km west of Baghdad, at longitude 44º12'40′ north and latitude 10′20º33º east. The land of the area is flat to semi-flat with a height of 34.1 m above sea level. The soil of the site is characterized as sedimentary with a mixed texture of silty clay loam. The soil was prepared for cultivation by plowing, smoothing and leveling it, and samples were taken from it randomly and representative of the soil of the field, then it was dried and ground with a wooden hammer and passed through a sieve with a diameter of 2 millimeters and mixed well and samples were taken for the purpose of conducting chemical analyzes. Table (1) shows the characteristics of the soil before planting.

Table (1): soil chemical properties before planting

Samples	Depth (cm)	pH	EC (dS. M^{-1})	Ca	Mg	Na	K	So_4	Cl	No_3	Co_3	HCo_3
				ppm								
1	0-25	7.6	38	1520	1750	4600	150	8160	7232	282	0	146
2	25-50	7.52	35	1300	1580	4209	140	7392	6027	205	0	134
3	50-75	7.4	22	760	936	3082	120	5472	3049	48	0	146

The experiment was designed according to the Completely Randomize Blocks Design (CRBD). Figure (1) shows the quinoa crop in flowering stage, where the field was divided into 9 pieces (experimental board) with dimensions of 8×5 meters representing three different treatments, namely (T1, saline well water, T2, mixed fresh and salty water, T3, fresh river water) with three replicates for each treatment. Seeds of quinoa (Chenopodium quinoa willd) were sown in the field on 28/11/2020, 85 gm / board was added, and the cultivation was carried out in the form of lines. Irrigation was carried out depending on the percentage of soil moisture, where irrigation is done when 50% of the available water in the soil is depleted, and the flow irrigation method was used.

Table (2) shows the chemical analysis of the irrigation water quality. Chemical fertilizers were used to fertilize the crop, as urea fertilizer (46% N) was added at an amount of 25 g N/m^2 in the form of two batches, the first after seven days of planting and the second batch after 30 days of planting for the purpose of increasing vegetative growth, and superphosphate fertilizer (21% P) was added 40 g/m^2 in one batch before planting. Chemical control was used for the purpose of protecting the plant from diseases and harmful weeds, where pesticide 2-4D was used at a rate of 4 liters/hectare to control the bushes that appear with crops with broad leaves. The data were analyzed statistically for the three treatments using the one-way ANOVA test and the least significant difference (LSD) test at the significance level (P>0.05) using the SPSS version 26

Figure (1): quinoa crop in flowering stage

Table (2): chemical analysis of the irrigation water quality.

SO_4	Cl	Mg	Ca	EC	PH	Water quality	Date
ppm				d.S.m^{-1}			
758	305	106	128	3.46	7.65	Well water	2020/9/10
300	141.8	12.7	64	0.836	7.6	river water	2020/10/17
782	312	113	136	3.5	7.7	Well water	2020/12/12
312	177	12.15	66	0.856	7.65	river water	2020/12/12
826	319	122	128	3.58	7.6	Well water	2020/12/24
307	163	12.75	60	0.850	7.5	river water	2020/12/24
883	336	152	136	3.7	7.7	Well water	2021/1/9
295	141	12.5	64	0.837	7.55	river water	2021/1/9
1171	376	170	130	3.97	7.8	Well water	2021/1/28
336	284	106	70.5	3.1	8	Well water	2021/2/3
480	464	126.5	46.2	0.87	7.8	river water	2021/2/3
518	106	122.5	48.6	0.84	7.72	river water	2021/2/18
960	319	134.6	170	3.7	8.25	Well water	2021/2/24
312	64	98	56	0.50	7.6	river water	2021/2/24
941	266	165	122.4	3.8	8	Well water	2021/3/3
480	191	53.4	118	0.96	7.8	river water	2021/3/3
1104	318	178	110	3.7	8	Well water	2021/3/18
466	166	76	78	0.89	7.8	river water	2021/3/18
1016	287	158	77	3.6	7.9	Well water	2021/3/31
624	411	96	100	3.6	8	Well water	2021/4/8
500	230	76	78	1.2	7.8	river water	2021/4/8

3. Results and discussion

3.1. Salinity impact on the yield of quinoa

Tables (3) and (4) show the soil chemical properties at the flowering stage and the end of the season for all treatments. The degree of soil interaction was neutral, while the values of soil salinity were high in the flowering stage, especially for the irrigation treatment with salty water, as the soil salinity was before planting (Table No. 1) 38 dS.m^{-1} and it became 39 dS.m^{-1} in the flowering stage when irrigated with saline water and the value of soil salinity was 36 dS.m-1 in the treatment of irrigating with mixed water and reached 27 dS.m^{-1} when irrigated with fresh river water in flowering stage.

Table (2): Chemical analysis of the irrigation water quality.

Table (3): Some Soil chemical analyzes at the flowering stage.

Samples	Depth (cm)	pH	EC (dS. M^{-1})	Ca	Mg	SO_4	Cl
				ppm			
T1	0 – 25	7.5	39	1563	1580	5470	14188
T1	25 - 50	7.3	37	1423	1327	4627	9723
T1	50 - 75	7.4	27	1138	978	3615	8462
T2	0 – 25	7.4	36	1443	1458	5380	12760
T2	25 - 50	7.3	32	1324	1278	4723	11420
T2	50 - 75	7.3	28	1125	875	3826	8744
T3	0 – 25	7.5	27	1162	948	3450	8500
T3	25 - 50	7.4	18	873	728	1722	6327
T3	50 - 75	7.4	14	622	644	1648	5642

Table (4) shows that the soil salinity decreased significantly at the end of the season, even when irrigated with saline water, and this was indicated by (Gertsis and Zoukidis, 2017) that the use of saline water in the cultivation of saline soils gradually reduces soil salinity. Also, soil salinity accumulates with depth as a result of irrigation operations, especially when irrigated with salty water, and this is consistent with what was found (Al-Azzawi et al., 2014).

Table (4): Some soil chemical properties at the end of the agricultural season

Samples	**Depth (cm)**	**pH**	**EC ($dS. M^{-1}$)**	**Ca**	**Mg**	**SO_4**	**Cl**
				ppm			
T1	0 – 25	7.3	14.4	1440	450	3470	8620
T1	25 - 50	7.36	23.3	2208	729	6594	9540
T1	50 - 75	7.4	27.5	3216	1032	8720	12340
T2	0 – 25	7.3	11.2	1020	520	2866	7230
T2	25 - 50	7.32	17.3	1350	718	4520	8811
T2	50 - 75	7.2	21.3	2670	988	6730	1085
T3	0 – 25	7.33	6.1	864	376	468	6714
T3	25 - 50	7.42	10.3	1104	380	638	7266
T3	50 - 75	7.45	18.6	2400	460	3828	7450

Figure (2) shows the yield values of the quinoa crop. We note that the yield values for all the study parameters were good, as a number of researchers indicated that the yield of the quinoa crop ranged from 500 to 1000 kg / hectare (FAO, 2016), (Maleki, et al, 2018).

The results showed that the productivity of the quinoa crop was good in all study treatments, although the soil salinity before planting (Table 1) was very high, due to the ability of the quinoa crop to grow in salinity conditions, as (Eisa ,et al., 2017) indicated that the quinoa crop can give good productivity even in Soil salinity up to 19 $dS.m^{-1}$

In general, the highest productivity values were using fresh irrigation water, because water directly affects the vital processes that take place inside the plant and the readiness, absorption and representation of nutrients, in addition to that the decrease in the salt concentration of irrigation water helps to increase vegetative growth and increase yield components (Al-Azzawi, et al., 2014). The results of the statistical analysis (Appendix) indicated that there were significant differences in the productivity values. The results indicated that the irrigation treatment with fresh water had the highest productivity values.

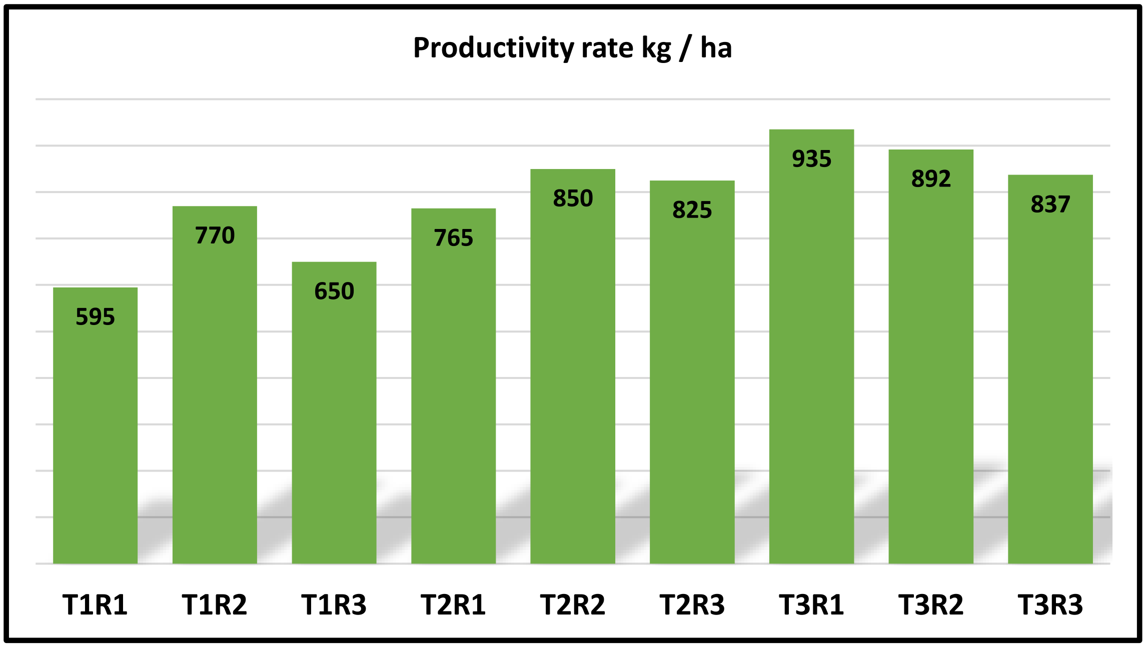

Figure (2): Quinoa crop yield rate

3.2. Statistical analyses

Table (5), (6) shows the result of the statistical analysis, the results show there are significant differences in the values of soil salinity during the stages of the agricultural season.

Table (5) analysis of variance (ANOVA table)

ANOVA			
Output			
	Sum of Squares	**df**	**Mean Square**
Between Groups	72444.667	2	36222.333
Within Groups	24659.333	6	4109.889
Total	97104.000	8	

Table (6) summary of statistical model

Tests of Between-Subjects Effects					
Dependent Variable:Ec					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	1134.000[a]	2	567.000	9.831	.001
Intercept	17787.000	1	17787.000	308.405	.000
Per	1134.000	2	567.000	9.831	.001
Error	1384.180	24	57.674		
Total	20305.180	27			
Corrected Total	2518.180	26			
a. R Squared = .450 (Adjusted R Squared = .405)					

4. Conclusion and Recommendations

A field experiment was achieved using the seeds of the quinoa crop at Al-Raed Research Station. The results showed that the soil salinity decreases significantly at the end of the agricultural season due to salty water, especially in the surface layer. The amount of rainfall during the plant growth period had an important role in the process of washing salts from the soil. The average length of quinoa plants was fairly similar in irrigation treatments with mixed water Irrigation treatment with fresh water demonstrates the ability of the quinoa crop to withstand salinization conditions. The productivity values of the quinoa crop were good and within the global productivity ranges for the crop Quinoa ranging from 1000-500 kg/ha. We recommend expanding the cultivation of quinoa in Iraq because it is a salt-tolerant crop, drought-resistant, and suitable for the climatic conditions.

Reference

Al-Azzawi, H. F. S., Ali, M. M. H., Nada, R. Z. ,2014, Studying the effect of high salinity water uses and water magnetization technology on water use efficiency and productivity of wheat, barley, white corn and yellow corn, *Ministry of Water Resources*, National Center for Water Resources Management.

Adolf, V. I., Jacobsen, S.-E., & Shabala, S. ,2013, Salt tolerance mechanisms in quinoa (Chenopodium quinoa Willd.), *Environmental and Experimental Botany*, 92, 43–54.

Angeli, V., Miguel Silva, P., Crispim Massuela, D., Khan, M. W., Hamar, A., Khajehei, F., ... & Piatti, C. ,2020, Quinoa (Chenopodium quinoa Willd.): An overview of the potentials of the "Golden Grain" and socio-economic and environmental aspects of its cultivation and marketization. Foods, 9(2), 216.

Aswad, H. 2011 Reclamation of Salinity-Affected Soils by Phytoremediation in Iraq. Master Thesis, *faculty of Agriculture. Baghdad University*.

Eisa, S. S., Eid, M. A., Abd El-Samad, E. H., Hussin, S. A., Abdel-Ati, A. A., El-Bordeny, N. E., Ali, S. H., Al-Sayed, H. M. A., Lotfy, M. E., & Masoud, A. M. 2017, Chenopodium quinoa'Willd. A new cash crop halophyte for saline regions of Egypt , *Australian Journal of Crop Science*, 11(3), 343–351.

Ewaid, S. H., Abed, S. A., & Al-Ansari, N. ,2019, Water footprint of wheat in Iraq. *Water*, *11*(3), 535.

FAO.,2016, Quinoa. Technical Assistance for Diet Strengthening Quinoa in Algeria, Egypt, Iraq, Iran, Lebanon, Mauritania, Sudan, Yemen. Food and Agriculture Organization of the United Nations.

Gertsis, A., & Zoukidis, K. ,2017, Irrigation with highly saline water: A new innovative water treatment system evaluated for vegetable production in greenhouse. European Water, (59), 331-337.

Huang, M., Zhang, Z., Zhai, Y., Lu, P., & Zhu, C. ,2019, Effect of straw biochar on soil properties and wheat production under saline water irrigation, Agronomy, 9(8), 457.

Hu, H., Shao, T., Gao, X., Long, X., & Rengel, Z. ,2022, Effects of planting quinoa on soil properties and microbiome in saline soil, Land Degradation & Development, 33(15), 2689–2698.

Jacobsen, S.-E., Mujica, A., & Jensen, C. R. ,2003, The resistance of quinoa (Chenopodium quinoa Willd.) to adverse abiotic factors. Food Reviews International, 19(1–2), 99–109.

Maleki, P., Bahrami, H. A., Saadat, S., Sharifi, F., Dehghany, F., & Salehi, M. ,2018, Salinity threshold value of Quinoa (Chenopodium Quinoa Willd.) at various growth stages and the appropriate irrigation method by saline water. Communications in Soil Science and Plant Analysis, 49(15), 1815-1825.

Turcios, A. E., Papenbrock, J., Tränkner, M. ,2021, Potassium, an important element to improve water use efficiency and growth parameters in quinoa (Chenopodium quinoa) under saline conditions, *Journal of Agronomy and Crop Science*, 207(4), 618–630.