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Effect of Domestic Treated Wastewater use on Three Varieties of Quinoa (*Chenopodium quinoa*) under Semi Arid Conditions

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***Abstract*—**The purpose of this work was to study the effect of the irrigation using waste water with various electric conductivities (T (0,92ds/m), EC3 (3ds/m) and EC6 (6ds/m) on three varieties of quinoa cultivated in a field south of Morocco. The follow up of the evolution of the chemical and agronomic parameters throughout the culture made it possible to determine the responses to the saline stress in arid conditions. Results showed that the salinity caused the depression of plant's height, and reduced the fresh and dry weight in the different parts of the three varieties plants. The increase of the irrigation water EC didn't affect the yield for the varieties. Thus, quinoa resisted to salinity and proved a behavior of a facultative halophyte crop. In fact, the cultivation of this using treated wastewater is feasible especially in arid areas for a sustainable use of water resources.

***Keywords*—**Quinoa, salinity, semi-arid, treated wastewater.

I. Introduction

FRESH water scarcity is becoming an increasingly acute problem primarily in arid and semi arid regions of the world. In the Mediterranean regions, water resources are limited, delicate, and very unequally distributed over space and time. During the second half of the 20th century, water demand has increased [7]. In some Mediterranean countries, the water use is approaching the limit level of available resources. The water supply is endangered by over-exploitation of a part of the renewable underground water (generating salt-water intrusion) and the exploitation of non-renewable resources (including fossil water) [5]. Consequently, development of new water resources is becoming crucial in order to attenuate the pressure on freshwater use. Treatment and use of waste water for irrigation in agriculture sector is one promising solution for an efficient integrated water management.

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Treated wastewater is being used in many countries throughout the world as a reliable source of water which can fulfill the gap between supply and demand in water sector [4]. The benefits from the use of treated wastewater are manifold especially to the countries that are facing chronic shortage of water supply and where the economy is mostly agri-based [6]. However, the feasibility of using treated wastewater for irrigation can vary according to: The total concentration of dissolved salts in the water and the concentrations of specific salts such sodium, phosphate and nitrates, soil type (e.g. permeability and drainability) and crop type (e.g. salt tolerance of particular species). In fact, salinity problems need to be attenuated by working on those three factors.

As the problems of salinity become more severe, the growing of alternative plants and crops suited to moderately saline conditions is required with the option of introducing them under-exploited, salt-tolerant minor crops. Salt tolerant plants may provide a logical alternative for many developing countries. Quinoa (*Chenopodium quinoa* Willd.) is a traditional Andean pseudocereal increasingly attracting attention because of its adaptability to produce in these unfavorable soil and climatic conditions. It has been cultivated in the Peruvian and Bolivian Andes for more than 7000 years [1]. On the other hand, quinoa has a very high nutritional value. Apart from the high protein content, the grains are also rich in vitamins and minerals. The great potential of this crop has not yet been fully exploited, mainly because of the lack of research on sustainable cropping systems and on management of biotic and abiotic constraints to production [3]. Quinoa is well adapted to grow under unfavorable soil and climatic conditions [2]. The objective of this study is to evaluate the response of quinoa to salinity stress with the use of treated waste water for irrigation. Thus, the feasibility of using treated waste water, with different salinity levels, for irrigation of quinoa was investigated. On the other hand, evaluate, in term of growth and yield, the differences in salinity tolerance between several quinoa varieties. Soil parameters were measured to characterize the effects of salinity level in irrigation water.

II. Materials and Methods

Three varieties (QS 0938, D 0708 & QM 1113) of quinoa were planted in simple rows after germination period on July 2010, under field conditions, in the experimental station of the Agronomic and Veterinary Hassan II Institute Campus, Agadir. The site is located in south West of Morocco and characterized by a semi-arid climate. Soil in this field is loamy and moderately rich in organic matter with a pH of 8.04 and an EC of 0.17 dS / m. The moisture field capacity corresponds to 30% of moisture; wilting point is equal to 15%. The Irrigation system chosen is drip irrigation (2l/h) by using soil moisture sensing and telemetry system for its management.

Plants were irrigated by using treated wastewater with three levels of salinity: EC1 as a control (0,92 dS/m), EC3 (3 dS/m) and EC6 (6 dS/m) obtained by adding sea water. Four replications were adopted for each treatment on plots of 12 m2 according to a split plot design showed in the figure 1.

Wastewater collected is domestic water treated by using Sheaffer system. The method of treatment "Sheaffer" is based mainly on aeration of the raw effluent during a period that depends on the load of organic wastewater. The average theoretical length of treatment varies from 30 to 40 days.

In terms of microbiological quality, irrigation water meets the WHO standards and classified type A (240 fecal coliforms/100 ml<1000; 250 fecal streptococci/100 ml<1000).

Statistical analysis was performed using the software “MINITAB” by adopting variance analysis ANOVA, generalized linear model with two factors treatment and variety.

TABLE I
TREATED WASTEWATER CHARACTERISTICS

Parameter	Content (mg/L)
NH_4^+	64.80
NO_3^-	99.20
P	150.00
K	08.19
Ca	66.80
Na	51.29
Cl	101.50
Mg	39.60
Total suspended matter	55.46
Suspended mineral matter	29.20
pH	7.77
EC (dS/m)	0.92
DBO5	21.00

Growth evaluation was monitored at three stages: vegetative, flowering and maturity by measuring leaf area (area measurement system), fresh and dry weight of the different parts of plant. Foliar analysis was carried out for each stage (chloride, sodium, total nitrogen). On the other hand, plant weight was measured every week. Soil analyses concerned moisture, pH, EC, Nitrate, Phosphorus, potassium, sodium and chloride content during the cited stages. Total production was measured to evaluate the yield of each variety and treatment.

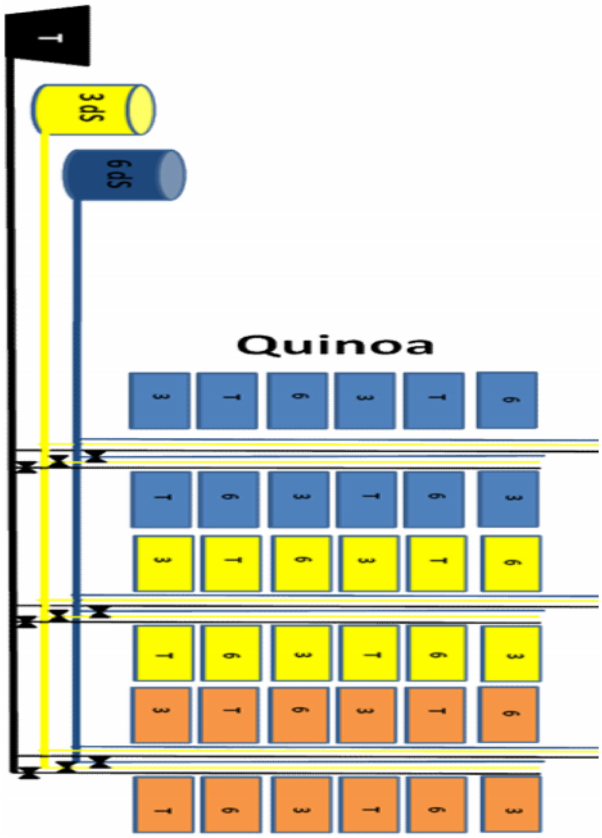


Fig. 1 Experimental design

III. Results and Discussion

A. Growth

Salinity affected significantly all growth parameters, and differences among varieties for all characteristics were significant. All growth parameters decreased with increasing salinity level. However, their sensitivity to salinity stress varied with the level of stress and variety. On the other hand, the interactions between varieties and salinity stress levels were also significant.

Pant height: The analysis revealed a highly significant difference in favor of the variety 3 that showed the highest average in the treatment respectively 107.05 cm 0,92 dS/m and under treatment 139.25cm 6 dS/m followed by the variety 2 with an average of 74.2 cm, respectively, under treatment 3 dS/m and 82 cm under treatment 0,92 dS/m. Indicating that the varieties 2 and 3 growed respectively at speeds of 1.33 cm/day 3.57 cm/day at thethird measurement and 1.44 cm/jday and 2.93 cm/day in the fourth and final measurement. What is in perfect agreement with the work of Wilson.C et al, 2002, under which there would be no significant reduction in plant height or weight to treatment costs greater than 11 dS /m. The slowdown in plants growth is manifested by short internodes, decreased growth rate and consequently a decrease in the total length of the plant. The salt causes a reduction in turgor, which induces the delay of the growth rate.

Leaf area: There was a significant difference between the leaf surfaces of the three varieties in stage 2 in favor of the variety D0708 and highly significant in stage 3 for the variety QS 0938.

In Stage 2, the variety D0708 showed an average maximum of 8008.67cm ² / plant under treatment 0.92 dS/ m followed by the variety QM 1113 with an average of 7557.8 cm ² / plant under treatment 6dS / m. In Stage 3, the variety QS 0938 gave the maximum average of 2092.18, 2106.42 and 1417.95 m2/ plant respectively in treatments 0.92, 3 and 6 dS / m. Which could be explained partly by a difference of nutrient uptake by different varieties due to different levels of treatment in stage 2 and on the other hand, the senescence of old leaves in stage 3.

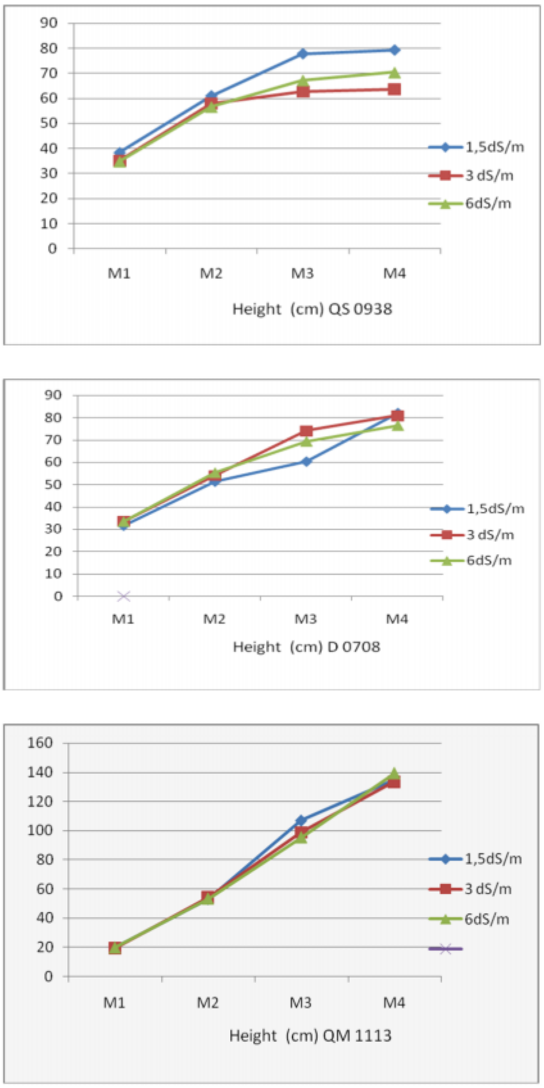


Fig. 2 Effect of different salinity levels on varieties in term of plant's height (in cm)

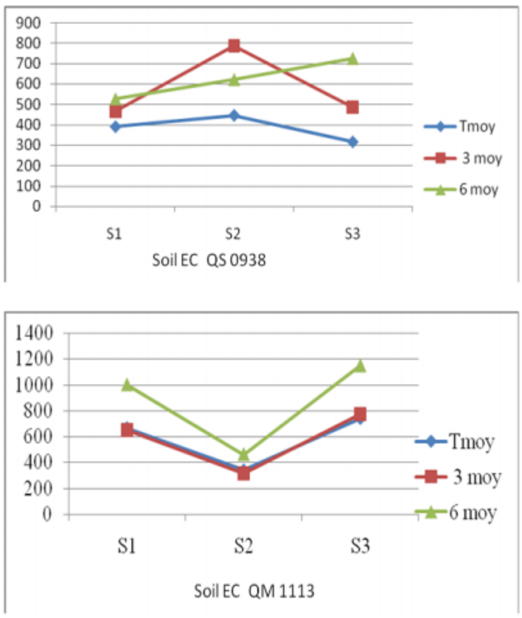
Fresh and dry weight: Statistically, no difference towards treatment was found. Within a single variety, no difference in behavior from 3 levels of treatment in term of fresh weight.

However, the varieties respond differently to these treatments. In stage 1 and 3, there was no significant difference between varieties, while in stage 2 the differences in fresh weight were significant in favor of the variety D0708 that has the highest weight average the 438.47g/plant, 390.52 g/plant and 325.67g/plant respectively, under treatment 0.92, 3 and 6 dS/m.

Regarding dry weight, sstatistical analysis revealed a significant difference between the dry weights at the stade3 for the variety D0708. This variety showed the highest mean dry weights are 212.12, 144.65 and 153.55 g/plant respectively to the treatments 0.92, 3 and 6 dS / m.

B. Soil parameters

The electrical conductivity at soil level is evolving differently from one variety to another and from one treatment to another. Among the variety QS 0938, there was an increase in electrical conductivity to the stage 2 then decrease to stage 3 and that for treatment 0.92 and 3dS/m. Treatment 6 dS/m has a different character, from stage 1 to stage 3 soil EC increased with an average 0.726 dS /m. Among the variety QM 1113 it was obtained a similar behavior to that of the variety QS 0938 for treatments 0.92 and 6 dS/m. Treatment 3ds / m has a different behavior, the electrical conductivity of soil increases from stage 1 to stage 2 then it stabilized until stage 3. Among the variety D 0708, there was an appearance quite different from the other two varieties, the electrical conductivity decreased from stage 1 to stage 2 and from there,. These differences in behavior of varieties according to treatments were revealed by statistical analysis. In Stage 1, the difference in change in the conductivity at soillevel was significant in favor to the variety D 0708 with the highest electrical conductivity: 0.66, 0.64 and 1.00 dS / m respectively for the treatment 0.92, 3 and 6 dS / m. In Stage 2, the difference is highly significant for the variety QS 0938 followed by the variety QM 1113. In Stage 3, the difference becomes very highly significant in favor to the variety of D0708 followed by QM 1113. These changes in the EC could be explained by accumulation of salt over time resulting from treated wastewater use.



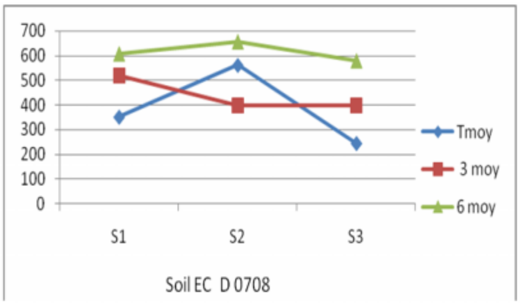


Fig. 4 Effect of waste water salinity level on soil's EC

Wastewater is rich in nitrates; in fact measuring its concentration in soil is crucial. The increase of EC was rapid during the vegetative stage; this is because the water brings large amounts of nitrate, which exceed the plant needs during stage, then the concentration increases from flowering until the end maturation phase where it begins to decrease.

C. Yield

The analysis revealed a significant difference in performance in favor of the variety QM 1113 with an average of 6.92 t/ha under treatment 6 dS / m followed by the variety D 0708 with an average of 5.65 under control treatment. Those results are in concordance with those found by Jacobsen et al. (2000) during one of their experience in the quinoa in Peru, Lima, where some of the characteristics they have measured as leaf area, biomass production and Seed yield showed the best responses in saline conditions between 10 and 20 dS / m.

IV. Conclusion

Under limited freshwater supplies conditions, agriculture will probably be forced to use increasingly marginal quality water, saline or treated wastewater.

In this context, this work aimed to monitor the behavior of three varieties of quinoa under different salinity levels of water and treated wastewater. The effects of salinity on physiological mineral and agricultural aspects were compared between the quinoa varieties.

Salinity stress had low effects on all the growth parameters. In term of growth, an increase of the EC level of applied irrigation water reduced slightly the plant's height, leaf area, fresh and dry weight measured at vegetative, flowering and maturity stage. In fact, growth reduction resulted in low reduction of yield for all tested varieties when EC levels increased.

Therefore, the analysis revealed a significant difference in performance in favor of the variety QM 1113 with an average of 6.92 t/ha under treatment 6 dS / m followed by the variety D 0708 with an average of 5.65 under control. Nevertheless, the yields obtained, even with the application of the EC6 treatment, were relatively higher in comparison with the ones obtained in normal cultivation conditions.

Quinoa crop can be the object of a deep research in order to introduce it in the cropping system of Agadir as a semi-arid region. Nevertheless, more efforts and works needs to be carried in term of waste water treatment technology and reuse and also in term of selection of more varieties of quinoa.

TABLE II
Effect of Salinity Level on Yield

Yield (T/Ha)	EC 1 (Control)	EC3	EC6
A0020	4,71d	3,87e	3,52e
A211	7,03 a	6,78a	6,43 b
A0057	6,77a	5,63c	4,85d

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