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Effect of Chemical Correction of Irrigation Water on a Barley Crop

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Abstract. The lack of fresh water for irrigation in the world and especially in arid and semi-arid areas is often posed as a major problem for agriculture, which requires research to valorize saline irrigation water. This work aims to study the impact of chemical correction of irrigation water quality on barley. The corrected waters were prepared from the raw waters by applying the doses of calcium represented by Ca(NO3)2 4H2O according to their soluble sodium content, whose aim is to balance the two sodium and calcium contents. The treatments are five types of raw water of different salinity S1, S2, S3, S4 and S5 as well as five types of corrected water S1C, S2C, S3C, S4C and S5C. The parameters studied are: length of the stems, length of the spike, number of grains per spike, grain yield, straw yield and the weight of 1000 grains. The results obtained show that the chemical correction has a positive effect on the length of the stems, the number of grains per spike, the grain and straw yield. Calcium correction reduces the harmful effect of sodium and alleviates the aggressiveness of salinity.

Keywords. Chemical correction, Barley, Water quality, Saline irrigation water.

1. Introduction

The efforts to increase agricultural production in arid and semi-arid regions are generally hampered by the lack of fresh water for irrigation. Therefore, it is often necessary to use lower quality water to meet crop water requirements [1].

Under these conditions, the rational use of salt water is essential to make good use of the water, reduce the effect of salinity and better promote the development of crops [2].

Irrigation with water rich in salts can lead to the fixing of sodium by the soil adsorption complex, thus a process of sodization, with its possible consequences for the properties of the soil: tendency to the dispersion of clays, to the degradation of the structure, loss of permeability and asphyxiation of plants [3].

These soils can be improved by the use of amendments which contain Ca, when added to water, increase the concentration of calcium in the water, thereby reducing sodium relative to calcium and SAR, improving thus the rate of infiltration [4]. In addition, the harmful effect of sodium on the soil or on the plant is all the more accentuated when sodium dominates in the medium. For irrigation water as long as the sodium does not reach 50% of the total cations, its action on the soil adsorption complex seems limited, above this value the danger is great, it results in waterproofing and soil sterilization[5].

The effect of sodicity on the plant is a toxic effect and induced nutritional problems due to the imbalance of the Ca/Na ratio [6]. It should be noted that the more or less balanced medium is less aggressive for the plants than the unbalanced medium. Thus, the toxicity of sodium chloride is less strong in the presence of calcium which plays an antagonistic role (Maume and Dulac, 1929 in [5]), [7]. According to Rengasamy [8], the presence of calcium in saline-sodic water limits the adsorption

of sodium by soil colloids and therefore prevents the formation of sodic soil with poor physical conditions. In addition, the calcium is required for many important processes in the plant [9].
The objective of this work is to determine the impact of the chemical correction of the quality of irrigation water by a calcium supply on a cereal crop (Barley) in the region of Biskra Algeria, aiming to reduce the harmful effect of sodium through the creation of a balanced environment favorable to the soil and the plant.

2. Materials and Methods

2.1. Geographic Location
The experiment is carried out on the land of the agronomy department at the University of Biskra, under greenhouse shelter covered with insect proof, the purpose of this greenhouse is to avoid the action of rain and violent winds and the possible damage of birds.
The province of Biskra is located in the south-east of Algeria, it is bordered to the north by the province of Batna and to the south by the provinces of El-Oued and Ouargla, it is also bordered to the east by the province of Khenchela, and in the west, the provinces of M'sila and Djelfa.
The province of Biskra is also called the capital of Ziban and the gateway to the Sahara, because of its strategic location, its area being estimated at more than 20,000 km², located at 34°48 North, and 5°44 East.

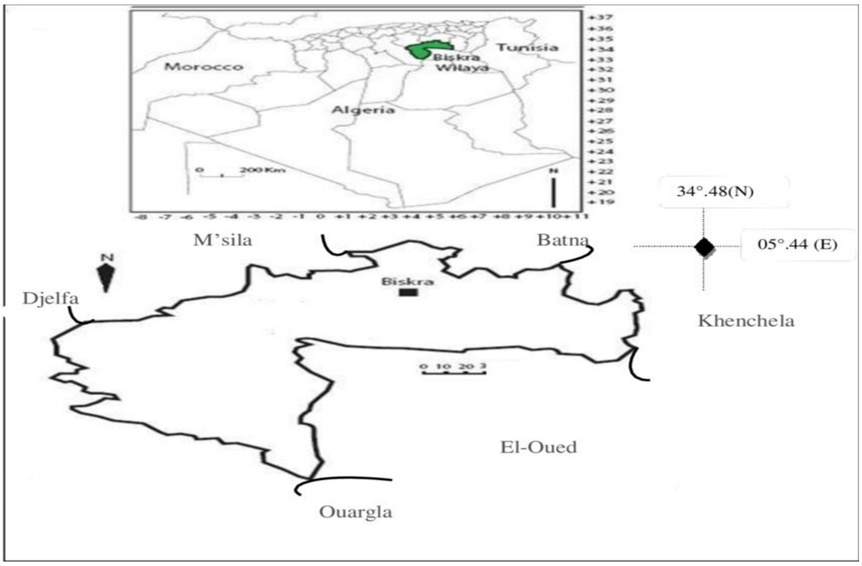

Figure 1. Position and geographical location of the Biskra region [10].

2.2. Soil
The soil used is that of the experimental land of the agronomy department of Biskra, it is a loamy clay soil, limestone (35%) and salty (CE 4.3 dS/m 1:5), its pH 8.09 and poor in organic matter (0.8%).

2.3. Irrigation Water
We made a collection of several samples of irrigation water from different regions of Biskra. These waters are subjected to precise chemical analyzes to choose the types of water that will be used in our experimentation. The main selection criteria are the electrical conductivity, which must be gradual, and the soluble sodium content, which must be higher than the soluble calcium in order to make the necessary calcium amendment. Five types of water chosen whose characteristics are grouped in Table 1.

Table 1. The chemical quality of irrigation waters.

Type of water	CE (mS/cm)	pH	Ca++ meq/l	Mg+ meq/l	K+ meq/l	Na+ meq/l	SO4- meq/l	Cl- meq/l	HCO3- meq/l
S1	2.84	7.86	6.00	8.60	0.19	13.92	9.44	13.50	3.25
S2	3.84	7.58	10.40	9.00	0.16	20.01	6.96	25.00	4.50
S3	4.83	7.28	12.00	9.00	0.16	26.43	10.24	35.00	3.75
S4	6.37	7.54	15.40	18.6	0.15	35.95	15.76	46.60	3.75
S5	7.68	7.52	25.80	20.2	0.48	38.15	31.6	41.00	2.50

The amounts of calcium added to irrigation water in the form of calcium nitrate $Ca(NO_3)2\ 4H_2O$ are based on the equivalence of their soluble sodium content and are presented in table 2.

Table 2. Quantities of calcium nitrates added to irrigation water.

	S1	S2	S3	S4	S5
soluble Na meq/l	13.92	20.01	26.43	35.95	38.15
soluble Ca meq/l	6.00	10.40	12.00	15.40	25.8
Ca deficiency meq/l Na – Ca	7.92	9.60	14.43	20.55	12.35
Amount of Calcium Nitrate for Balance Na: Ca g/l	0.93	1.13	1.70	2.42	1.45

2.4. Experimental Protocol

The treatments used in this experiment are ten treatments represented by five types of original or raw water S1, S2, S3, S4, S5 and five types of corrected water S1C, S2C, S3Cc, S4C, S5C which are the same raw water but enriched with different amounts of calcium as explained above. The experiment is carried out in pots of vegetation filled with a quantity of 4.5 kg of soil with a layer of gravel placed on the base of each pot. The test plant used is a variety of barley (Hordeum vulgare L.) called Fouara R1. Barley was sown on 25/11/2019 evenly in the pots, each pot was irrigated with water representing its specific treatment. Phosphate and potassium fertilizer was added at the start of the trial mixed with the soil, while nitrogen fertilization was split twice during cultivation. The experiment was conducted until grain harvest on 15/05/2020. The experimental device used is of the complete random block type, consisting of 10 treatments and 3 repetitions. The treatments are S1, S1C, S2, S2C, S3, S3C, S4, S4C, S5 and S5C.

2.5. Statistical Analysis

The analysis of variance (ANOVA) is carried out by XLSTAT 2014.5.03 and the comparison of the means is made by the Fisher LSD test at 5%.

3. Results and Discussion

3.1. Grain Yield

According to the grain yield graph (Fig 2), it can be seen that almost all the corrected treatments have higher grain yields than those of the raw treatments despite the increase in the salt load of the corrected waters induced by the addition of calcium salt. This shows the favorable and balancing effect of calcium in the nutritional environment [11, 7]. The lower yield of S5c compared to S5 may be due to the very high CE. The best performance is obtained by S2C. The analysis of variance shows significant differences where the S2C, S4C and S3C treatments show the best results and rank in the same homogeneous group compared to the other treatments. This improvement in yields is explained by a significant increase in the number of grains per ear, following an improvement in their fertility [12].

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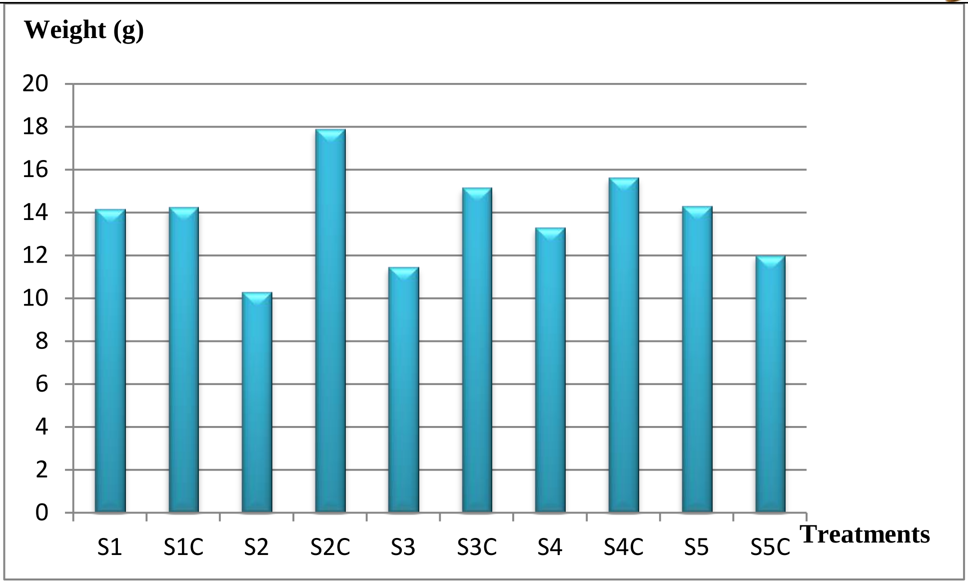

Figure 2. Effect of irrigation water correction on grain yield.

3.2. Straw Yield

The results show that the best straw yields are obtained by the corrected treatments S5C, S3C, S2C (Fig 3) which shows that the correction used has a positive effect, the low yield is obtained by the S4 treatment. The analysis of variance shows a significant effect according to Fisher's test (LSD). The corrected S5C treatment has the highest straw yield (28.06 g). It appears that nitrogen added with calcium played an important role in the production of aboveground biomass for the corrected treatments. Nitrogen remains the determining element for cereal production [13]. In addition, S5 irrigation water is relatively rich in potassium, which seems to play a positive nutritional balance role with calcium in the face of salinity and sodium. Also K reduces the negative effect of Cl [14]. This action is clearer in biomass production than in grain production.

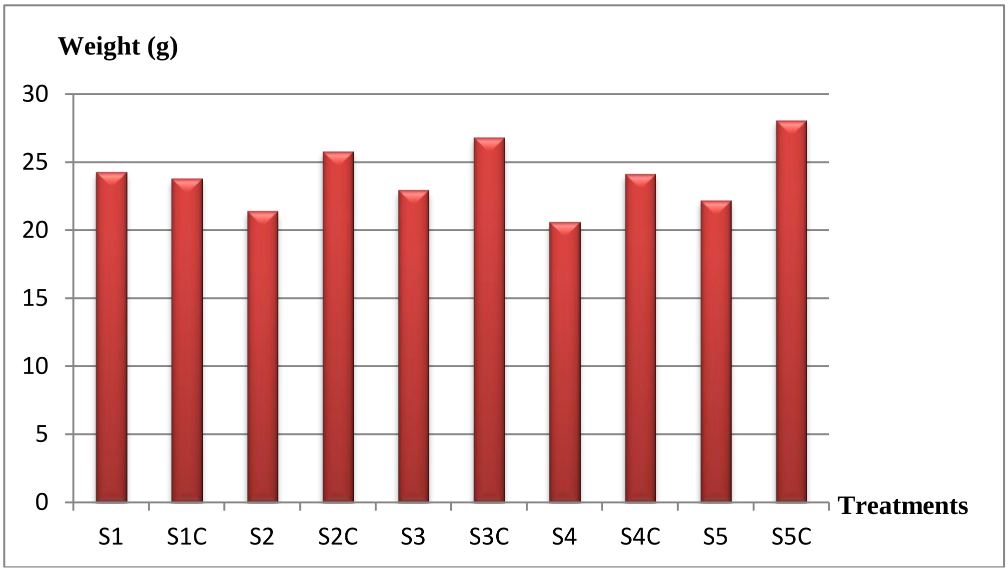

Figure 3. Effect of irrigation water correction on straw yield.

3.3. Number of Grains Per Ear

The effect of irrigation water correction is very clear on the number of grains per ear (Fig 4), we note that the best number of grains per ear are obtained by the corrected treatments compared to the other treatments which shows the effect of added Ca on the number of grains per ear. The addition of Ca has a favorable action in the nutritional environment [15], by reducing the inhibitory effect of salts [16]. The analysis of variance shows that the S2C and S4C treatments form the first group, it is at the same time that these two treatments give the best grain yield, so this improvement in yields is explained by a significant increase in the number of grains per ear as has already been pointed out.

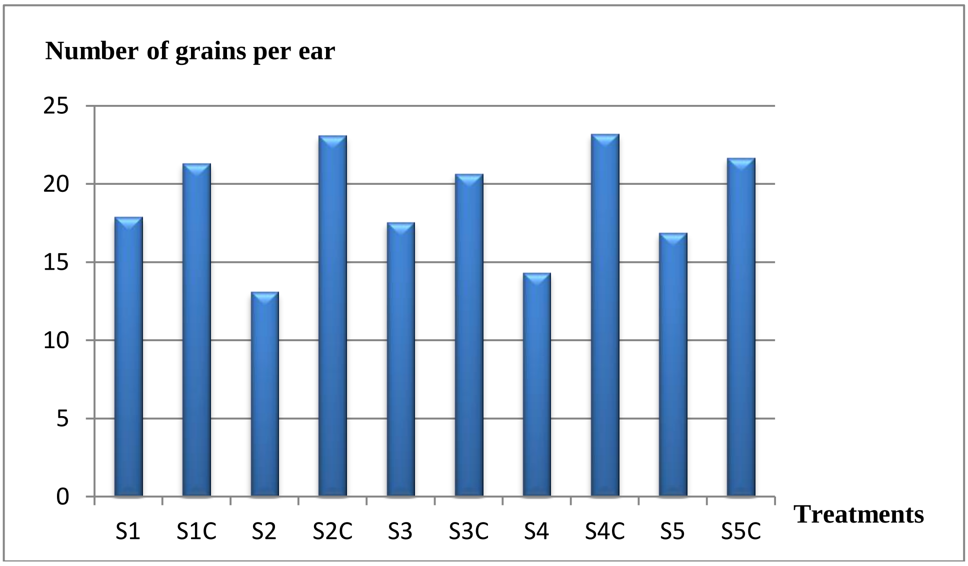

Figure 4. Effect of irrigation water correction on the number of grains per ear.

3.4. 1000 Grain Weight

According to the graph (Fig 5), we notice that the highest 1000 grain weight is approximately 47 g represented by the S2 treatment, however the lowest 1000 grain weight is approximately 34 g represented by the S5C treatment. It is noted that there is an inverse correlation between the weight of 1000 grains and the number of grains per ear, especially in treatments S2, S4 and S5, the weight increases when the number of grains per ear is low. Correcting water quality changes the morphogenetic scheme of plants [17].

The analysis of variance shows that there are significant differences between the treatments, the first group is represented by S2, S4, S5. Therefore, the effect of the correction is positive on the number of grains per ear but generally negative on the weight of 1000 grains.

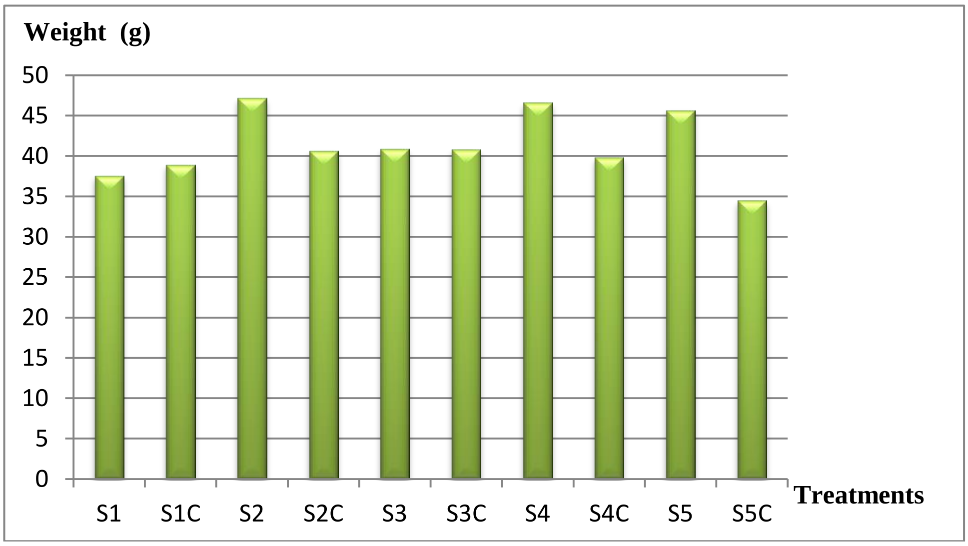

Figure 5. Effect of irrigation water correction on 1000 grain weight.

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3.5. Ear Length

The obtained results (Fig 6), show an improvement in the length of the ear of the treatments corrected like the number of grains per ear. All the corrected treatments show longer ears than the raw treatments. Indeed, the addition of Ca improves plant growth under salt stress [11].
The variance analysis shows that S5C has the longest ear length (4.6 cm) on the other hand S2 presents the shortest length (3.9 cm). This probably means that calcium nitrate plays an important role in the heading morphology of the plant.

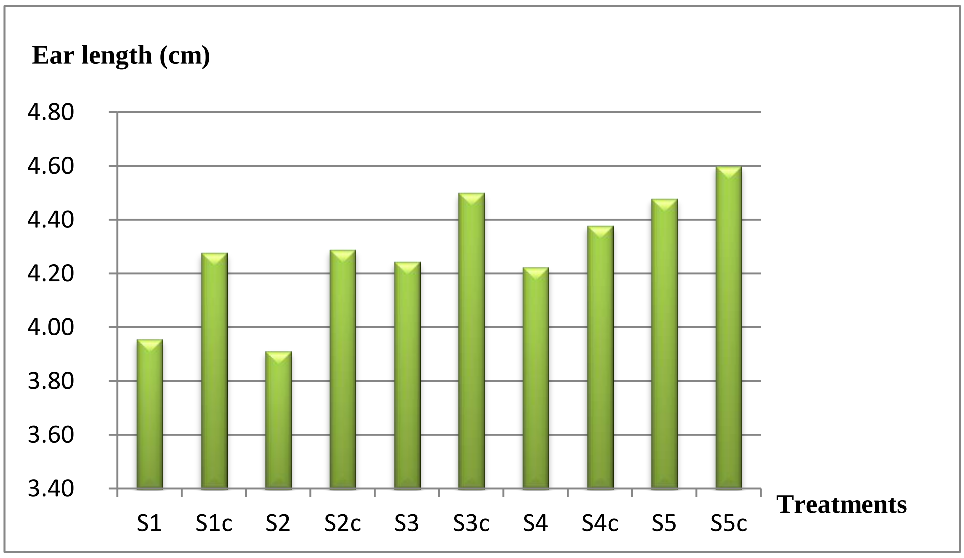

Figure 6. Effect of irrigation water correction on ear length.

3.6. Stems Length

According to the graph (Fig 7), it can be seen that the effect of irrigation water correction on stem length is clear. Corrected treatments generally have longer stem lengths than other treatments, the calcium amendment has a significant effect and this can be explained by the effect of Ca which alleviates the negative effect of salinity [18, 19] following its role in the balance ionization and the maintain of selective permeability of the membrane [20]. In addition, it seems to us that this improvement results from the effect of the nitrogen included in the added amendment, which has a marked effect on growth. The best length is obtained by the S5C treatment. It should be noted that barley is a tolerant plant to salinity and for this reason we have not seen a decrease in certain parameters with the increase in the electrical conductivity of the waters used.

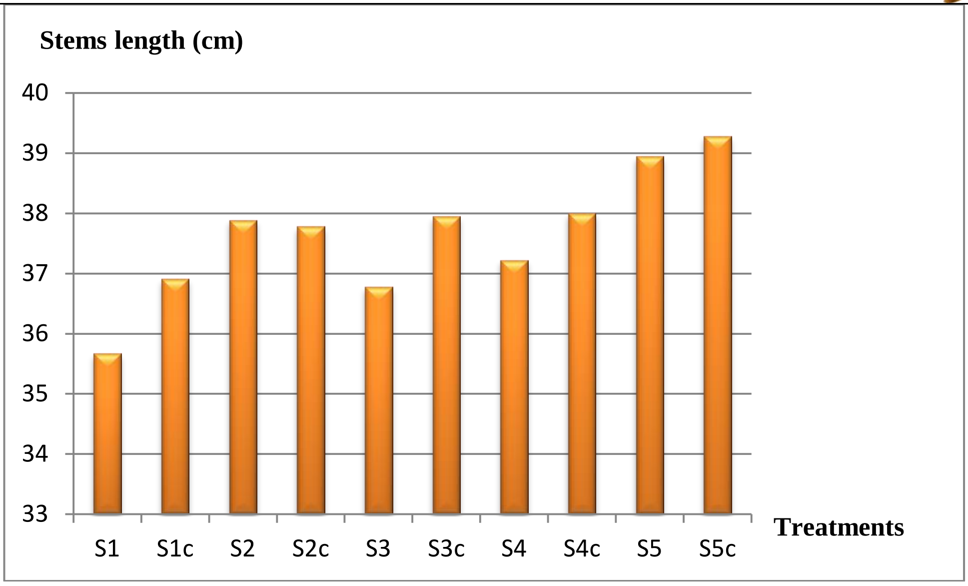

Figure 7. Effect of irrigation water correction on stem length.

Conclusion

The obtained results at the end of this experiment show that treatments irrigated by corrected water generally have the best results compared to treatments irrigated by natural raw water. These results are clear on the parameters grain yield, straw yield, number of grains per ear, ear length and stem length. The observed improvement is probably the result of the addition of calcium which has balanced the nutritional environment and has a positive action on the soil in the face of the aggressiveness of salinity and sodium. Several researchers have indicated that Ca can alleviate the inhibitory effect of NaCl and therefore contribute to the improvement of root growth [21, 22 and 23]. Thus, Lopez and Satti [24] found that the addition of Ca to a saline nutrient solution increases root length despite the increase in concentration because the toxicity of Ca is very low. In addition, we can also note the effect of the nitrogen included in the calcium nitrate amendment, especially on the growth parameters. Finally, it can be said that the chemical correction of the quality of irrigation water can play an important role on cultivated plants by creating a favorable environment despite the increase in the salinity of the corrected water.

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