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# Effect of Domestic Treated Wastewater use on Three Varieties of Amaranth (*Amaranthus* spp.) under Semi Arid Conditions

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***Abstract*****—**An experiment was implemented in a filed in the south of Morocco to evaluate the effects of domestic treated wastewater use for irrigation of amaranth crop under semi-arid conditions. Three varieties (A0020, A0057 & A211) were tested and irrigated using domestic treated wastewater EC1 (0,92 dS/m) as control, EC3 (3dS/m) and EC6 (6dS/m) obtained by adding sea water. In term of growth, an increase of the EC level of applied irrigation water reduced significantly the plant's height, leaf area, fresh and dry weight measured at vegetative, flowering and maturity stage for all varieties. Even with the application of the EC6, yields were relatively higher in comparison with the once obtained in normal cultivation conditions. A significant accumulation of nitrate, chloride and sodium in soil layers during the crop cycle was noted. The use of treated waste water for its irrigation is proved to be possible. The variety A211 had showed to be less sensitive to salinity stress and it could be more promising its introduction to study area.

***Keywords*****—**Amaranth, 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. It's the case of the Mediterranean countries characterized by a severe water imbalance, especially those located in the North Africa and Middle East region. In those areas, demands on fresh water resources are increasing due to population growth, increased per capita consumption, industrial and agricultural activities. 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 [5]. 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. Amaranth is used for its grain and is also consumed as a cooked vegetable in many parts of the world. Owing to its high nutritive value and a wide adaptability to diverse environments, amaranth has been considered a promising crop for marginal lands and semi-arid regions [1]–[3]. The prospects for future cultivation of salt-tolerant, high-yielding genotypes of amaranth are very encouraging. However, despite a substantial amount of literature on plants responses to salinity stress, little information is available on amaranth.

The general objectives of this study were, on the one hand, to better understand the response of amaranth 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 amaranth was investigated. On the other hand, evaluate, in term of growth and yield, the differences in salinity tolerance between several amaranth varieties. Soil parameters were measured to characterize the effects of salinity level in irrigation water.

## II. Materials And Methods

Three varieties (A0020, A0057 & A211) of amaranth 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.

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.

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 |

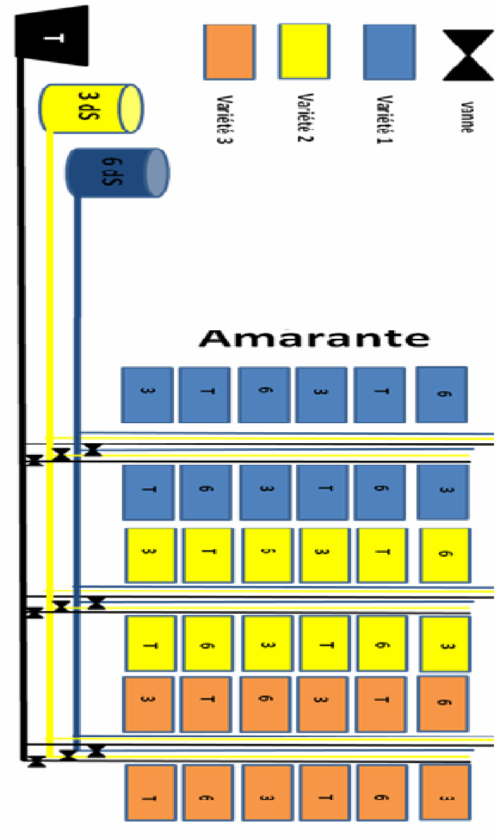



Fig. 1 Experimental design

## III. RESULTS AND DISCUSSION

### *A. Growth*

Salinity stress had significant effects on all growth parameters, and differences among varieties for all characteristics were highly significant. The interactions between varieties and salinity stress levels were also significant. All growth parameters decreased with increasing salinity level. However, their sensitivity to salinity stress varied with the level of stress and variety.

Pant height: The statistical analysis showed significant difference between treatments starting from the flowering stage. As a result, when salinity level increases from 0.92 dS/m (control) to 3 and 6 dS/m, plant height was reduced. The comparison between plant heights of different varieties showed a growth reduction of about 5 % to 10.4 % for A211, 4 % to 9 % for A0020 and 9.3% to 25% for A0057 respectively for the treatment, EC3 and EC6 compared to the control. In fact, A0057 was the most sensitive variety in response to salinity stress. 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 (Hsiao, 1973).

Leaf area: Statistical analysis revealed a significant difference between the leaf areas of different treatments. Indeed, a reduction of 24.5% to 37.4% for A0020, 12.5% to 15.2% for A211 and 49.3% to 61% for A0057, for EC3 and

EC6 treatments respectively, when compared to control. This shows that leaf area is affected by an increase in electrical conductivity of irrigation water (Figure 2). According to Baba (1985), a dose of 150 mM NaCl reduce leaf area, both in a susceptible variety than in a tolerant variety. So the leaf area decreases when salinity level increases.

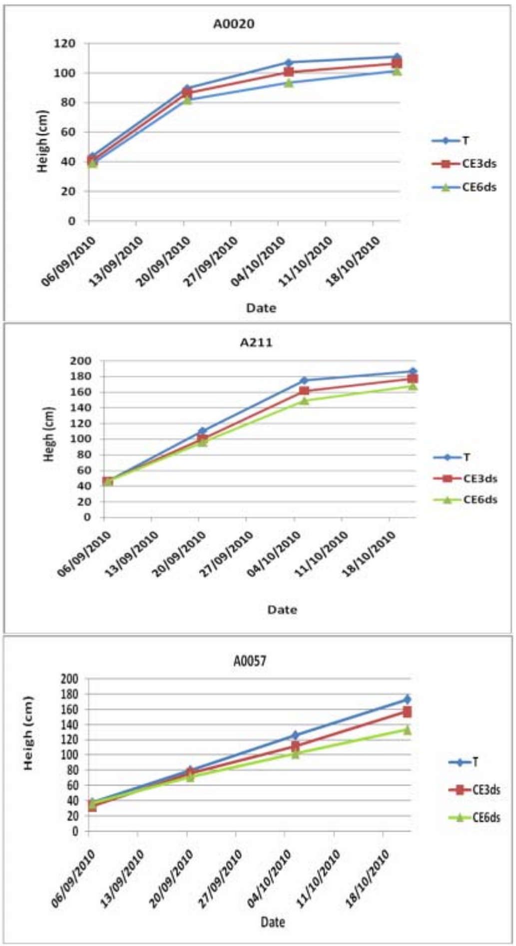
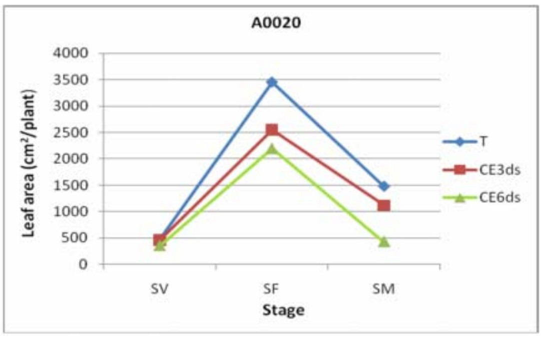



Fig. 2 Effect of different salinity levels on varieties in term of plant's height (in cm)



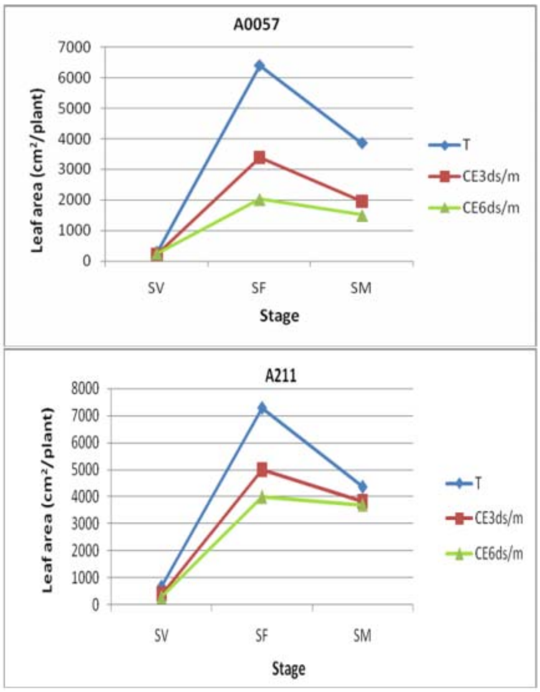




Fig. 3 Effect of salinity level in treated wastewater on leaf area

Fresh and dry weight: Significant effect of salinity on fresh weight of root was revealed by statistical analysis. Increasing salinity level decreased roots fresh weight. However, the increase in electrical conductivity affected the fresh weight of the root variety A0020 more than for A211 and A0057 varieties which were less affected during the end of the cycle. In addition to that, the fresh weight of leaves of the variety A0020 is more influenced by the increase of EC (Table 2). Statistical analysis showed a highly significant difference between the fresh weights of different treatments. According to Tukey, these varieties are divided into two homogeneous groups: one group, a, comprising A0020 and A0057 varieties and a group b with varieties A0057 and A211. Statistical analysis showed a highly significant difference between the stem fresh weights with respect to different treatments. According to Tukey, these varieties are divided into two homogeneous groups: group a (A0020) and group b (A0057 and A211). Indeed, the reduction of stem fresh weight was important for A0020 and especially for the treatment EC6.

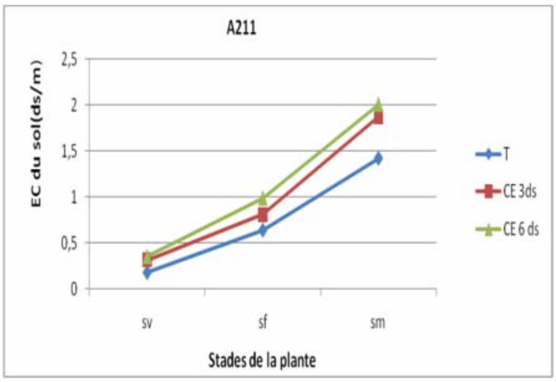
Regarding dry weight, roots had a significant increase during the first phase of growth for all treatments but the control has an important increase. In the one hand, Statistical analysis showed a highly significant difference between the root dry weights for the different treatments, on the other hand, they showed a significant difference between the leaves dry weights of different treatments. Low values of the dry weight recorded in the most saline treatments during the entire cycle can be explained by the fact that salt reduced stomata on the epidermal surfaces of leaves, cell volumes, relative rate of leaf expansion, and fresh and dry weights of leaves [2]. Varieties A0020 and A211are the most affected by the increase in the EC. Statistical analysis revealed a significant difference between the dry weights of the different treatments. A0020 is the most affected variety when EC was increased.The presence of salt in irrigation water led to a decrease in growth and leaf area of all varieties. Both in terms of fresh weight at the level of dry weight, salt have affected the different plant parts for all varieties. The salt effect is more pronounced in roots and leaves of A0020 variety than the stem level. However, the roots of A0057 and A211 varieties were more sensitive than their leaves and stems. A0020 is the most affected variety compared to the other two ones which behave almost in the same way against salinity. These results are similar to those of Sadik and Trabelsi (1989), who had worked on the responses of five tomatoes varieties irrigated with saline waters confirming that a dose of 100 mM NaCl causes a reduction of dry and fresh matter of all plant's parts specifying that stems and roots are more affected than leaves.

TABLE II
REDUCTION OF FRESH AND DRY WEIGHT UNDER SALINITY LEVEL:

| Variety | Fresh weight reduction | | | | | |
|---|---|---|---|---|---|---|
| | Roots | | Leaves | | Stems | |
| | EC3 | EC6 | EC3 | EC6 | EC3 | EC6 |
| A0057 | 39% | 43% | 21% | 33% | 34% | 37% |
| A0020 | 4% | 61% | 19% | 65% | 25% | 74% |
| A211 | 13% | 43% | 29% | 35% | 21% | 38% |
| | Dry weight reduction | | | | | |
| | Roots | | Leaves | | Stems | |
| | EC3 | EC6 | EC3 | EC6 | EC3 | EC6 |
| A0057 | 12% | 41% | 22% | 55% | 15% | 23% |
| A0020 | 14% | 40% | 18% | 31% | 19% | 49% |
| A211 | 35% | 40% | 34% | 42% | 55% | 35% |

*B. Soil parameters*

Soil EC increased progressively in soil during the crop cycle as shown in the figure 3. The statistical analysis showed a significant difference between the EC of the different treatments. Indeed, the soil EC was 0.30 dS/m in the beginning, that was increased gradually up to 1.4 dS/m (T=control), 1.8 dS / m (EC3) 2,01dS/m (EC6) for the variety A211 range; 1.38 ds / m (T) 1.67 dS / m (EC3), 1.92 dS/m (EC6) for the variety A0020, and 1.31 dS/m (T) 1.93 dS/ m (EC3), 2.12 dS/m (EC6) for the variety A0057.



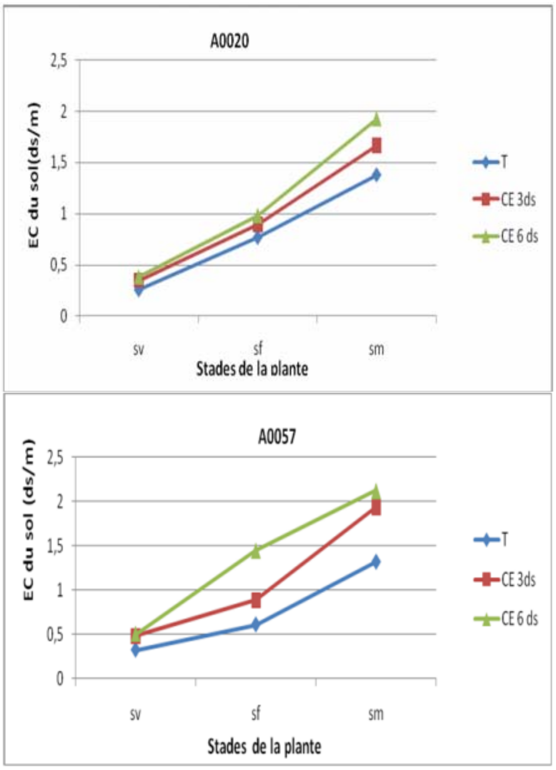
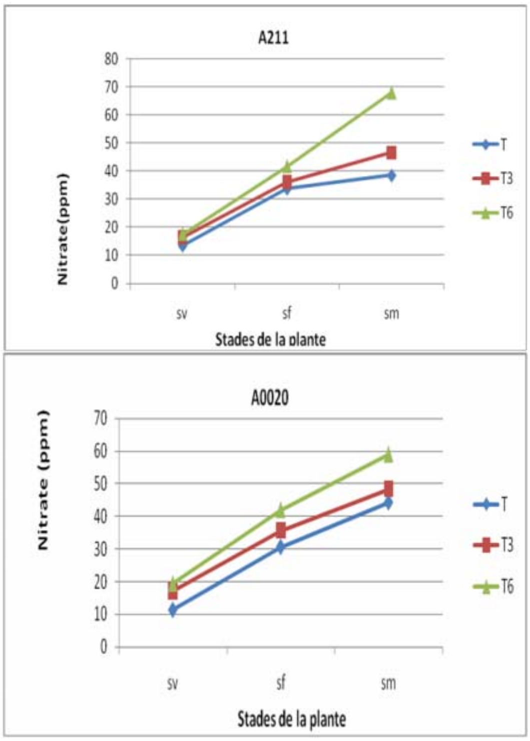




Fig. 4 Effect of waste water salinity level on soil's EC

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.



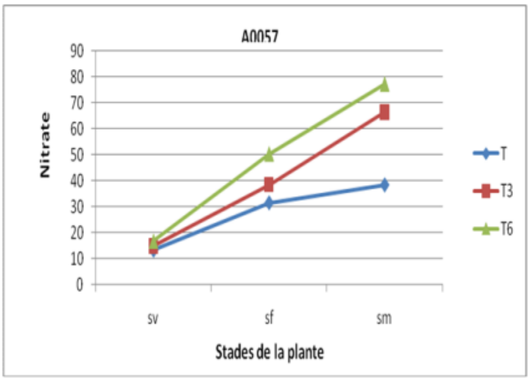
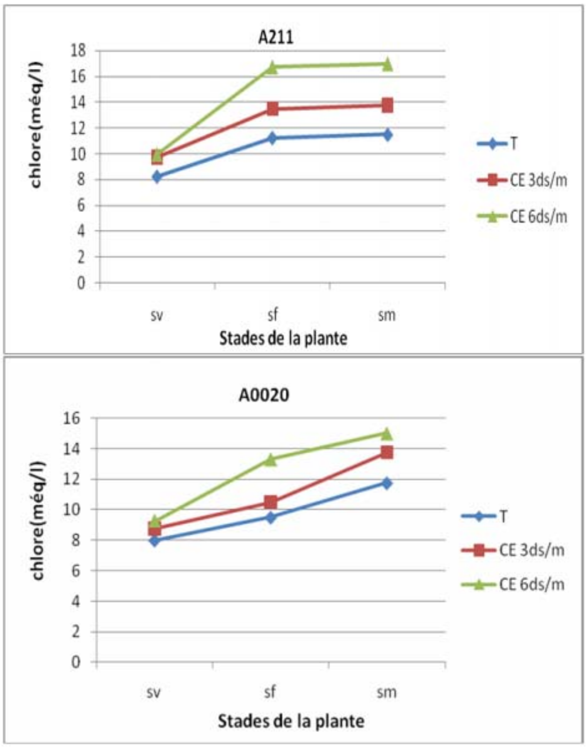



Fig. 5 Effect of waste water salinity level on soil's nitrate concentration

It is found that the chloride concentration increases significantly trough the crop cycle which is due to its accumulation in the soil. This can be explained by the used water type (waste water + sea water) which is rich in chloride. Statistical analysis indicates a highly significant difference between the concentrations of chlorine for the different treatments. The accumulation progresses with an increasing in electrical conductivity of irrigation water. In fact, treatment EC6 indicates the highest concentrations: 15.00 meq/L, 16.70 meq/L and 17.00 meq/L, followed by treatment EC3: 13.75 meq/L, 13.00 meq/L and 13.75 meq/L respectively for A0020, A0057 and A211 varieties. The control treatment indicates lower accumulation of chloride: 11.75 méq/L, 11.50 meq/L and 11.50 meq/L respectively for varieties A0020, A0057 and A211.



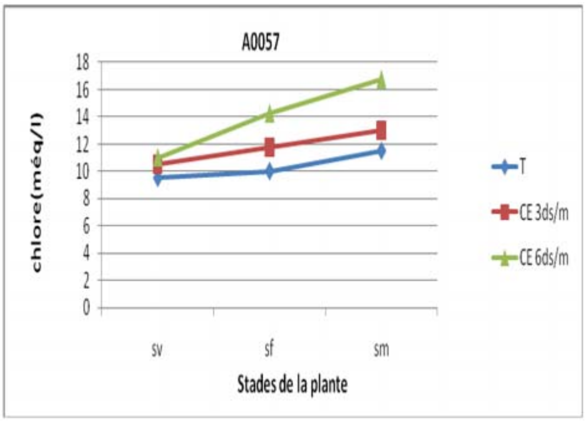
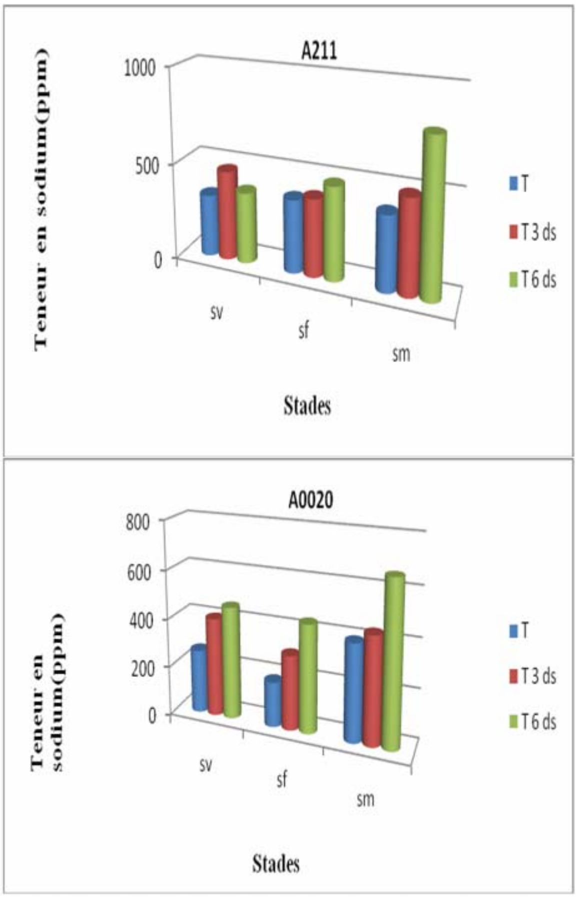




Fig. 6 Effect of waste water salinity level on soil's chloride concentration

Sodium concentration increased gradually during the crop cycle (Figure 6). This accumulation of sodium increases with an increasing in irrigation water conductivity. Statistical analysis indicates a highly significant difference between treatments. The control had lower sodium concentration. Sodium concentrations varied from 387.7 ppm, 488.6 ppm and 799.4 ppm for A211, from 394.1 ppm, 658.8 ppm and 435 ppm for A0020 and from 200.5 ppm, 513.8 ppm and 605.3 ppm for A0057 respectively for control, EC3 and EC6.



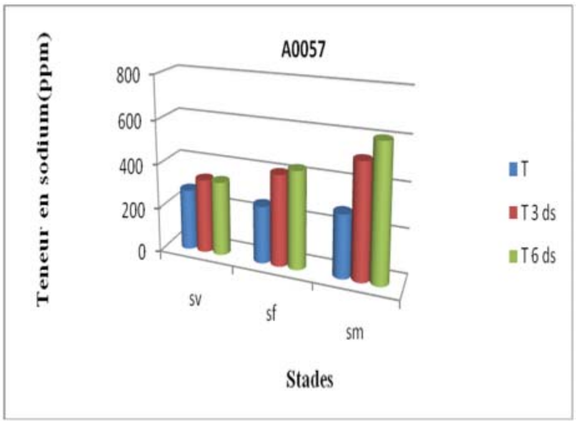



Fig. 7 Effect of waste water salinity level on soil's sodium concentration

Irrigation with different saline water had caused an increase in soil electrical conductivity. This result is due to the accumulation of sodium and chloride. The movement of mineral elements in soil is related to water migration. Thus, a gradual evolution of mineral contents was noted during the cycle. The increase of chlorine can be explained by its mobility in soil, while that of sodium is less marked because of its fixation on exchange sites. The estimation of salts concentration in soil is important in order to assess their impact on soil from an environmental point of view. In fact, accumulation of salt in soil should be monitored especially with the use of treated waste water and saline water.

### *C. Yield*

Increasing the EC of irrigation water leads to a reduction in yield from 17.8% to 25.2% for A0020; from 6.9% to 28.3% for A0057, from 3.6% to 8.6% for A211 respectively for EC3 and EC6 compared to the control (0.92 ds). The yields of A0020 and A0057 varieties are more affected by salt stress, while the yield of A211 variety was slightly affected. Statistical analysis showed a highly significant difference between different treatments. Nevertheless, the obtained yields, even with the application of EC6 treatment, were relatively higher comparing to the ones obtained especially for A211. The reduction of yield is directly related to a growth reduction.

TABLE III
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 |

## IV. CONCLUSION

In the future, 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 amaranth varieties under different salinity levels of water and treated wastewater. The effects of salinity on physiological mineral and agricultural aspects were compared between the Amaranth varieties.

Salinity stress had significant effects on all the growth parameters. The differences noted among varieties concerning all the characteristics studied, were highly significant. The interactions between varieties and salinity stress levels were also significant. All growth parameters decreased with an increasing salinity level. However, their sensitivity to salinity stress varied with the level of stress and the variety. Therefore, the effect of salt was more pronounced in the roots and leaves of A0020 variety than at stems level. However, roots were more sensitive than leaves and stems for A0057 and A211. Consequently, the yield was reduced. Significant differences were noted in term of yield for the different varieties under salt stress. Nevertheless, the obtained yields, even with the application of the EC6 treatment, were relatively higher in comparison with the ones obtained especially for A211. In fact, the variety A211 showed a promising productivity and salt tolerance, as consequence, it can be the object of a deep research in order to introduce it in the cropping system of Agadir as a semi-arid region.

The use of treated waste water for irrigation of amaranth can be an alternative solution to reduce the use of fresh water; nevertheless, more efforts and works needs to be carried in term of waste water treatment technology, monitoring of soil salinization and selection of other new tolerant crops to salt and drought.

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