



Reduce the negative effects of saline irrigation water on quinoa (*Chenopodium quinoa* L.) seedling growth with humic acid

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THIS STUDY was carried out in the Botany Department's laboratory at the Faculty of Science, Derna University, from January to April 2023. The objective was to investigate the impact of humic acid on the germination and vigor of quinoa seedlings subjected to varying salinity levels in the irrigation water. The experiment utilized three distinct salinity concentrations (1000, 2000, and 3000 ppm) alongside a control group, as well as three different concentrations of humic acid (0.2%, 0.4%, and 0.6%) compared to a control. A completely randomized design was implemented with three replications. The findings indicated that the application of humic acid effectively mitigated the adverse effects of saline irrigation water, enhancing both the germination rates of quinoa seeds and the morphological traits of the seedlings. The incorporation of humic acid into the agricultural soil resulted in a notable increase in germination percentage, seedling height, and leaf area, which positively influenced both the fresh and dry weights of the plants in comparison to the control treatments.

Keywords: Quinoa, Salinity, Humic acid, Seedling vigor.

Introduction

Quinoa (*Chenopodium quinoa* Wild L.) is a highly nutritious crop with minerals, vitamins, and a balanced amino acid profile that includes lysine and tryptophan, making it an excellent substitute for rice. Given its nutritious importance, increasing quinoa cultivation is critical (Mohamadpoor et al., 2024; Ali et al., 2018). Quinoa recently is one of globally most popular health foods, where its seeds gluten-free, contain all nine essential amino acids. It is highly protein content, fiber, potassium, calcium, magnesium, vitamin E, B-vitamins, iron, phosphorus, and many antioxidants (Awadalla and Morsy 2017).

Quinoa is a salt-tolerant plant that has the potential to become an important crop in arid and semi-arid regions and saline habitats and has expanded in many parts of the world to meet new market niches for gluten-free foods (Adolf et al., 2013; Ruiz et al., 2014).

Abiotic stress, particularly drought and salinity, are the most critical variables in limiting plant growth and development, particularly during the germination stage. The rise in global demand for nutritious and healthy food has prompted researchers to look for ways to produce products in marginal areas that are inefficient for agricultural production due to adverse weather conditions, low soil fertility, and good quality irrigation water scarcity (Amerian et al., 2023; Adams et al., 1998). Quinoa's importance stems from its adaptability and ability to grow in harsh climatic conditions, as well as its high nutritional content, which makes it an ideal crop for

cultivation in saline and drought-prone lands. Demand for quinoa cultivation has increased due to its high protein content, nutritional elements, including balanced amino acids, and high mineral concentrations (Bazile et al., 2016).

Young quinoa leaves have recently been utilized as both fresh and cooked vegetables. Quinoa's high-quality vegetable protein makes it a strong choice for improving global food production. Quinoa is often regarded as one of the most important and nutritious foods due to its resistance to abiotic stressors (Amerian et al., 2023).

Adding humic acid as a soil amendment can boost nutrient availability, enhance soil chemical properties, and promote quinoa plants' growth while mitigating the detrimental effects of saline irrigation water. Where humic acid substantially impacts soil salinity, pH, soil organic matter, nutrient availability, and plant absorption (Hany K. Abdelaal et al., 2025; Rekaby et al., 2023; Wang et al., 2003).

Also, Amerian et al., 2023 reported that humic acid increases quinoa germination and seed growth in salt stress situations. Humic acid enhances product performance by enhancing nutrient absorption and altering antioxidant defense processes. Humic acid promotes osmotic control by sustaining water absorption under salinity stress.

Humic acid promotes plant growth and physiology by improving photosynthetic intensity, nutrient uptake, cell membrane permeability, and hormone

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Received: 17/05/2025; Accepted: 14/07/2025

DOI: 10.21608/AGRO.2025.386000.1700

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activity in response to abiotic stress (Goel, and Dhingra, 2021; Abu-Ria et al., 2023) .

The aim of the study was to evaluate the assessment of quinoa cultivation under different levels of irrigation water salinity, and to evaluate the role of humic acid in mitigating the negative effects of irrigation water salinity on the growth of quinoa seedlings.

Materials and Methods:

Experimental methodology

Study site

This experiment was conducted in the laboratory of the Botany Department - Faculty of Science, Derna University during 2023 to study the effect of using humic acid on the germination and strength of quinoa seedlings under the influence of different levels of salinity of the irrigation water used.

Experimental design

The effect of added four different concentrations of humic acid in soil (0 %, 0.2 %, 0.4 % and 0.6 %) for water salinity mitigation was studied at three different concentrations of irrigation water (1000 ppm, 2000 ppm, and 3000 ppm) compared to tap water (control) to determine the efficiency of humic acid improving germination properties. The experiment was carried out in plastic bags after mixing soil with humic acid under open field conditions, where they were planted using a completely random design in three replicates, each replicate containing 30 seeds in two pots each replicate (overall 96 pots) and irrigated with three concentrations of water compared to tap water.

Studied Characters and Measurements

❖ Germination percentage (%): The percentage of germination was estimated after 7 days of sowing according to (Abd-El-Hamid & Bugaev, 2020; Allafe & Adam, 2022).

❖ Morphological characteristics of seedlings were recorded on seedlings during three growth stages:

after 45, 60 and 75 days of sowing. (The average of ten seedlings each characteristic).

1. Seedlings height (cm).
2. Leaf area per seedling (cm²).
3. Fresh and dry weight (gr.).
4. The number of leaves per seedling .

Statistical Analysis

All data were analyzed of variance (ANOVA) at a 5% significance level was used to assess the differences among treatments after all data were analyzed using the statistical program SPSS software.

Results and Discussion:

Germination percentage (%)

Effect of irrigation water salinity on quinoa seed germination

The following graph (1) shows the effect of salinity concentration of irrigation water used on the germination percentage of quinoa seeds. The data shows the negative effect of salinity of irrigation water on germination percentage. Using irrigation water with a concentration of 3000 parts per million (ppm) led to a 6.7% decrease in germination percentage compared to the control, where the germination percentage was recorded at 78.3%, while it reached 85% when using tap water (control). On the other hand, when using irrigation water with concentrations of 2000 and 1000 ppm, there were no differences in the germination percentage of quinoa seeds, but it also decreased by 1.7% compared to the control, where both recorded a germination percentage of 83.3%. This is consistent with several other previous studies that have shown that salinity negatively affects germination rate and seedling vigor. (Wang et al., 2022), demonstrated this effect on canola seed germination, and (Vicente-Sánchez et al., 2023), demonstrated this effect on quinoa.

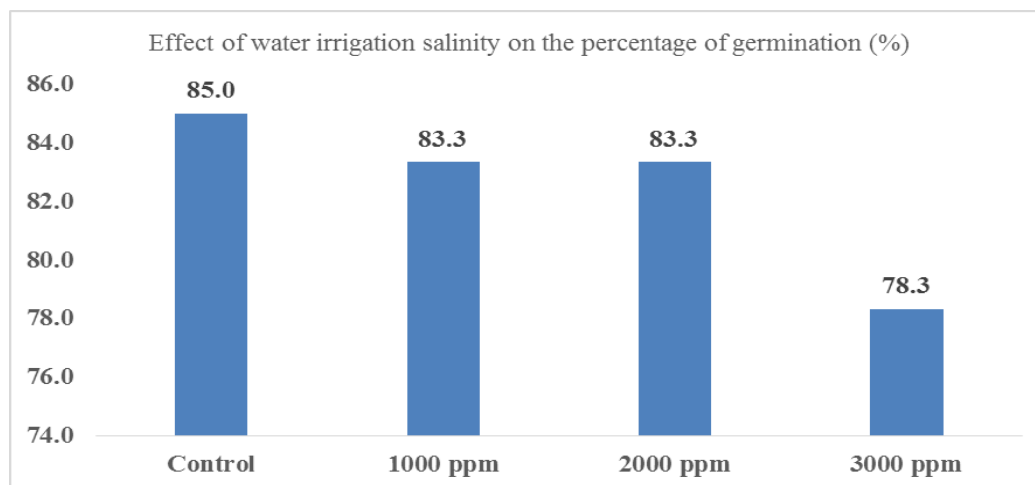


Fig. 1. effect of water irrigation salinity on the percentage of germination (%).

Effect of adding humic acid on the germination percentage of quinoa seeds

The results in figure (2) showed clear significant differences among the different concentrations of humic acid. The use of humic acid increased the germination percentage of quinoa seeds, and despite the differences between the different concentrations, they all outperformed the control (without adding humic acid). We find that the germination percentage increased by 4%, 3%, and 3% for the three concentrations of humic acid (0.2%, 0.4%, and 0.6%), respectively, compared to the control, which

had a germination percentage of 85%. This also agrees with many previous studies and research that have demonstrated the role of humic acid in improving the properties of soils containing salts, as well as mitigating the negative effects of irrigation water salinity, as demonstrated by (Rekaby et al., 2023), when they used humic acid to overcome the negative effects of irrigation water salinity on quinoa plants. Similarly, (Amerian et al., 2023) recommended the use of humic acid to improve germination and growth of quinoa seedlings under salt stress conditions.

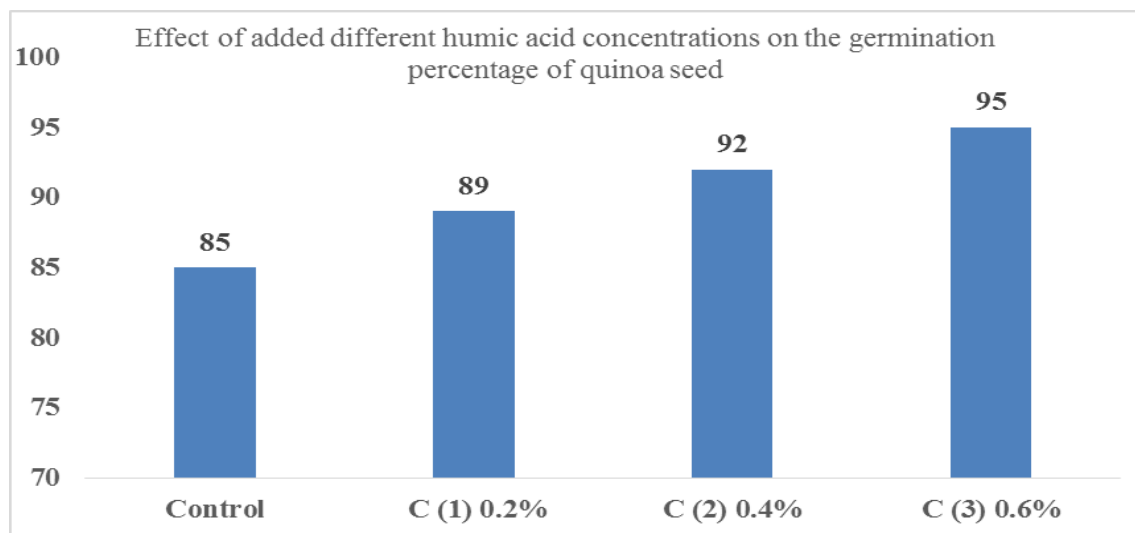


Fig. 2. effect of added different humic acid concentrations on the germination percentage of quinoa seed.

Morphological characteristics Impact of using humic acid on seedling height under salt stress conditions

The data in Table (1) illustrates the effect of adding humic acid on the height of quinoa seedlings under different salt stress concentrations. The results demonstrate the positive effect of using humic acid on increasing plant height under different salinity levels, as we notice the negative effect of saline irrigation water during the three sampling stages. As a result of the negative effects of salinity, we find that increasing the salinity concentration of irrigation water led to a decrease in plant height in each growth stage as well as a reduction in the rate

of plant height increase during the three stages. We find that when plants were irrigated using water with a salinity concentration of 3000 ppm, plant height decreased by 13.4%, 16.7%, and 13.4% compared to the control during the first, second, and third sampling, respectively. On the other hand, humic acid contributed to improving plant growth performance, as it increased plant height during the three sampling stages, as well as under the influence of different salinity concentrations. However, the effect varied depending on the concentration used. We find that the best results appeared when using humic acid at a concentration of 0.6% with different salinity concentrations during the three sampling stages.

Table 1. Impact of using humic acid on quinoa seedling height under water salt stress conditions.

Treatment	45 days after sowing				60 days after sowing				75 days after sowing			
	Humic Acid concentrations											
Salinity	Control	0.2%	0.4%	0.6%	Control	0.2%	0.4%	0.6%	Control	0.2%	0.4%	0.6%
Control	8.2	8.7	8.9	9.6	9.6	10.5	11.6	11.8	11.2	12.5	13.4	13.6
1000 ppm	7.8	8.5	8.7	9.4	9.3	9.9	10.2	10.9	9.9	10.8	11.4	12.9
2000 ppm	7.7	8.3	8.7	9.1	9.0	9.7	10.1	10.7	9.9	11.1	11.1	12.3
3000 ppm	7.1	7.9	8.0	8.6	8.0	8.3	9.3	10.3	9.7	10.6	10.9	12.2

Impact of irrigation water salinity on leaf area (cm^2) of quinoa seedlings

The data in figure (3) shows the effect of irrigation water salinity on the leaf area of quinoa seedlings during the three sampling stages, 45, 60, and 75 days after sowing. The data shows the negative effect of salinity, which increases with increasing salinity concentration. Although the leaf surface area increases from one irrigation stage to the next, the rate of increase decreases across stages with increasing soil salinity. We also note that the maximum leaf area reached 0.89 cm^2 in the third sampling stage at age 75 days when using tap water. On the other hand, when irrigated with saline water

at a concentration of 3000 ppm, the leaf area decreased by 25.8% compared to the control. On the other hand, using humic acid led to enhance the leaf area of quinoa seedlings. The results show a positive effect of using humic acid, which led to an increase in leaf area, and the rate of increase increased during the sampling stages with an increase in the humic acid concentration from 0.2% to 0.6%. During the first stage, we observed that the use of 0.6% humic acid led to an increase in leaf area of 42.5%. During the second stage, the increase was 28.2%, and during the third stage, it was 20.9% compared to the control (figure 4).

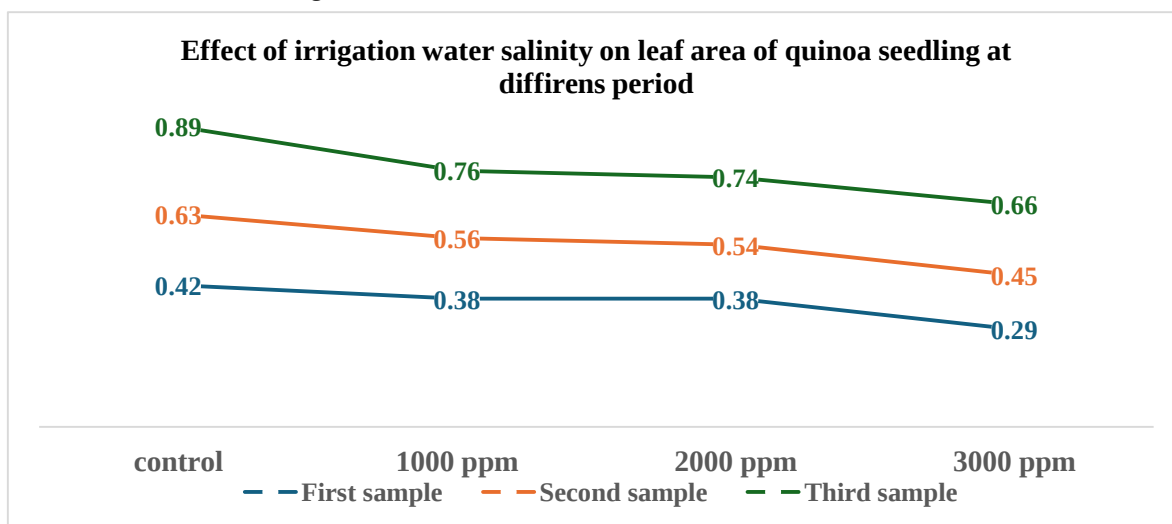


Fig. 3. effect of irrigation water salinity on leaf area of quinoa seedling at different periods.

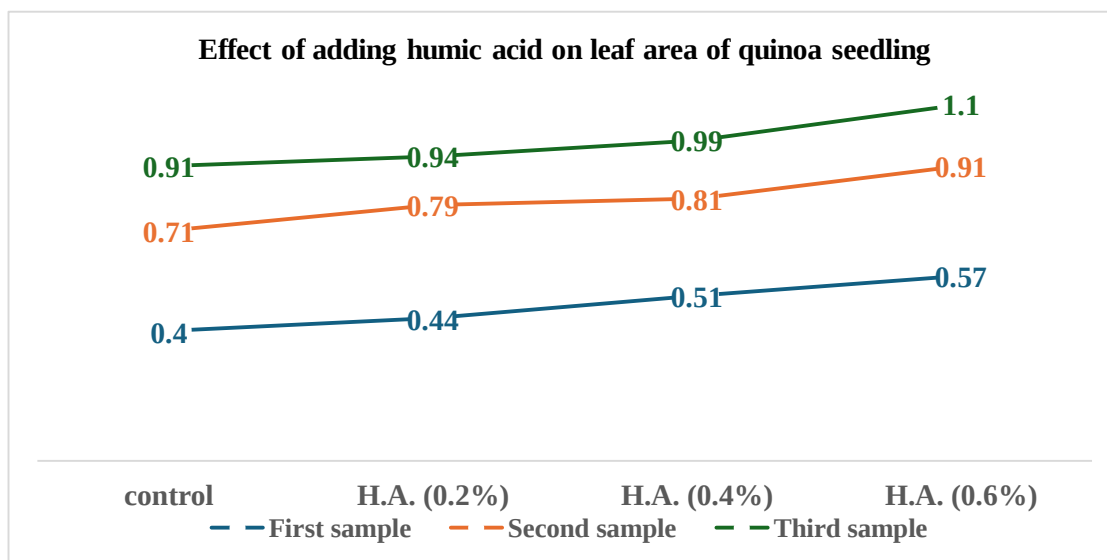


Fig. 4. effect of adding humic acid on leaf area (cm^2) of quinoa seedling at different periods.

The data in Figure (5) illustrates the effect of different salinity concentrations on the fresh weight of quinoa seedlings during the three sampling stages (45, 60, and 75 days after planting). The results

showed that increasing the salinity concentration of irrigation water led to a decrease in the rate of fresh plant weight during the three growth stages, as the weight increased in quinoa plants irrigated with tap

water (control) compared to the other salinity concentrations. Increasing the salinity concentration of irrigation water led to a decrease in fresh weight, where the decrease increased with increasing

concentration by 14.4%, 15.4%, and 29.4% compared to the control for the three irrigation water concentrations, respectively, during the third growth stage.

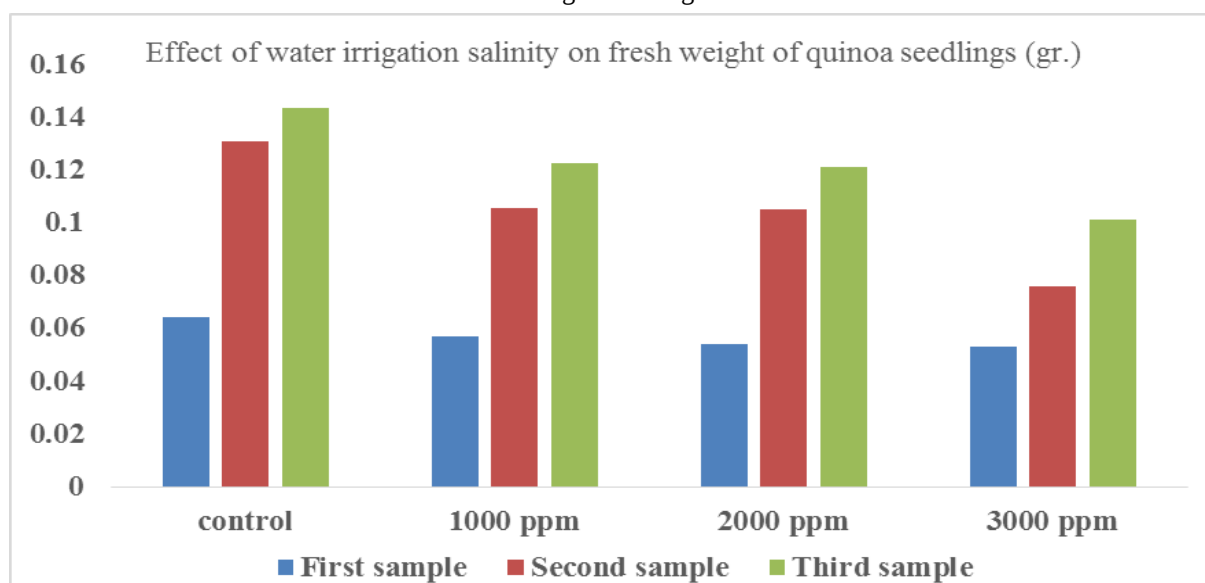


Fig. 5. effect of irrigation water salinity on fresh weight (gr.) of quinoa seedling at different periods.

Figure (6) illustrates the effect of irrigation water salinity on dry weight and dry matter accumulation in quinoa seedlings. We note the negative effect on dry matter accumulation (grams/plant), as we observe an increase in dry matter accumulation in the control treatment during the three sampling stages, and a decrease in dry matter accumulation

with increasing irrigation water salinity concentration. Dry matter accumulation during the first stage of growth in the control treatment increased by more than two-fold compared to dry matter accumulation when using saline irrigation water at concentrations of 2,000 and 3,000 ppm. The increase was 23.6% when irrigated with saline water at a concentration of 1,000 ppm.

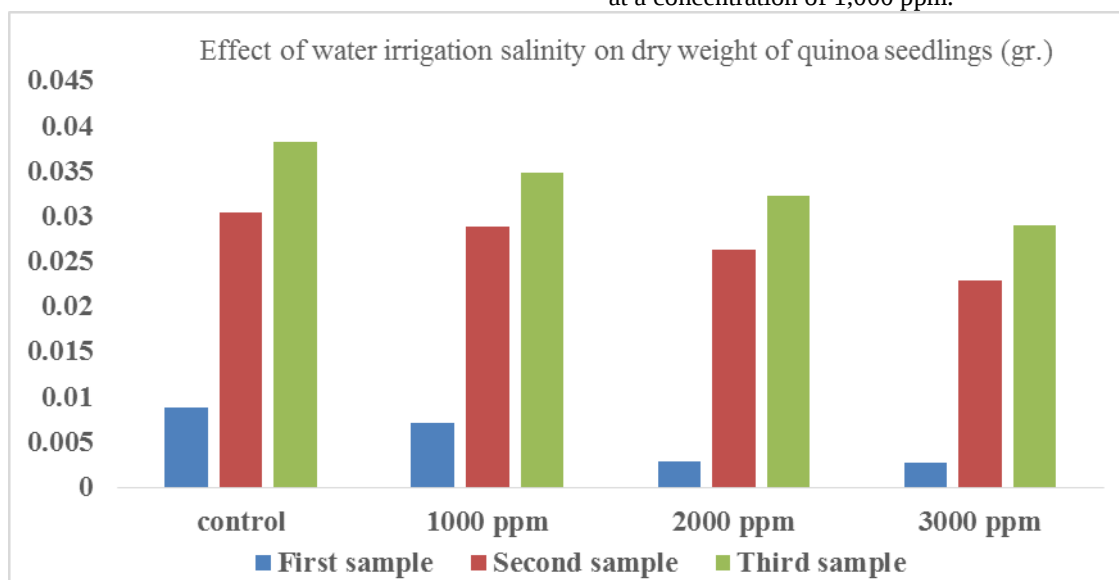


Fig. 6. effect of irrigation water salinity on dry weight (gr.) of quinoa seedling at different periods.

Figure (7) shows the effect of using humic acid on the fresh weight of quinoa seedlings under the influence of different levels of irrigation water salinity. The results show that the use and addition of humic acid to agricultural soil improved seedling

growth and subsequently increased plant fresh weight during the three sampling stages. We also note that this positive effect increased by increasing the rate of humic acid application from 0.2% to 0.6%. Using humic acid at a concentration of 0.6%

increased the fresh weight of seedlings by rates of 44%, 22.3%, and 28.9% during the three growth

stages, respectively, compared to the control.

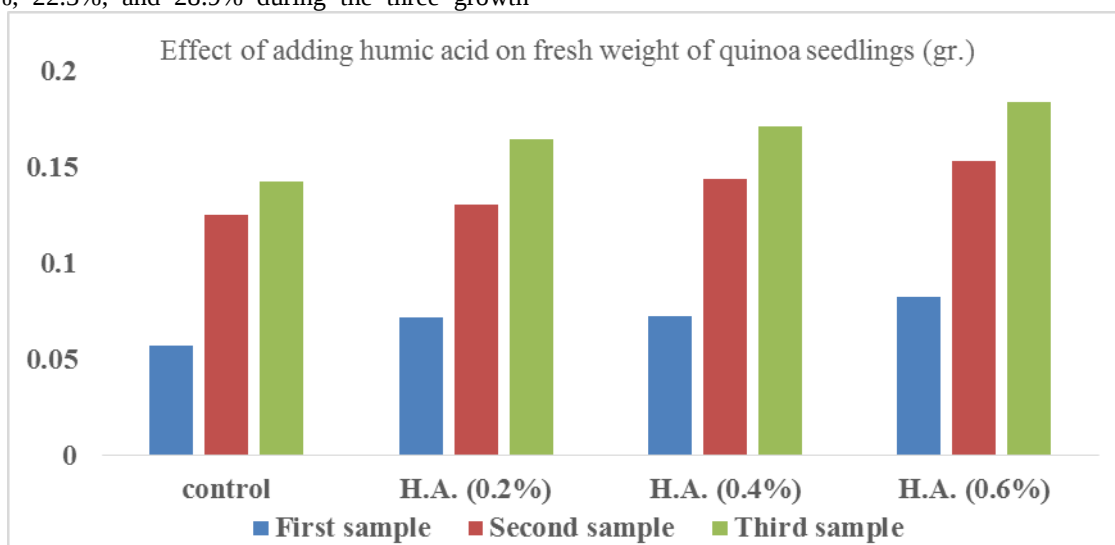


Fig. 7. Effect of adding humic acid on fresh weight (gr.) of quinoa seedling at different periods.

The results shown in Figure (8) illustrate the effect of adding humic acid on the dry matter accumulation of quinoa seedlings under the influence of different levels of irrigation water salinity. It demonstrates the positive effect of using humic acid, which increased with increasing concentration. Despite improving dry matter accumulation in quinoa seedlings during

the three different growth stages, it differed greatly with different humic acid addition rates. We find that when using humic acid at a concentration of 0.2%, the dry weight increased by 21.8% during the third stage compared to the control, which amounted to 0.0349 g/plant.

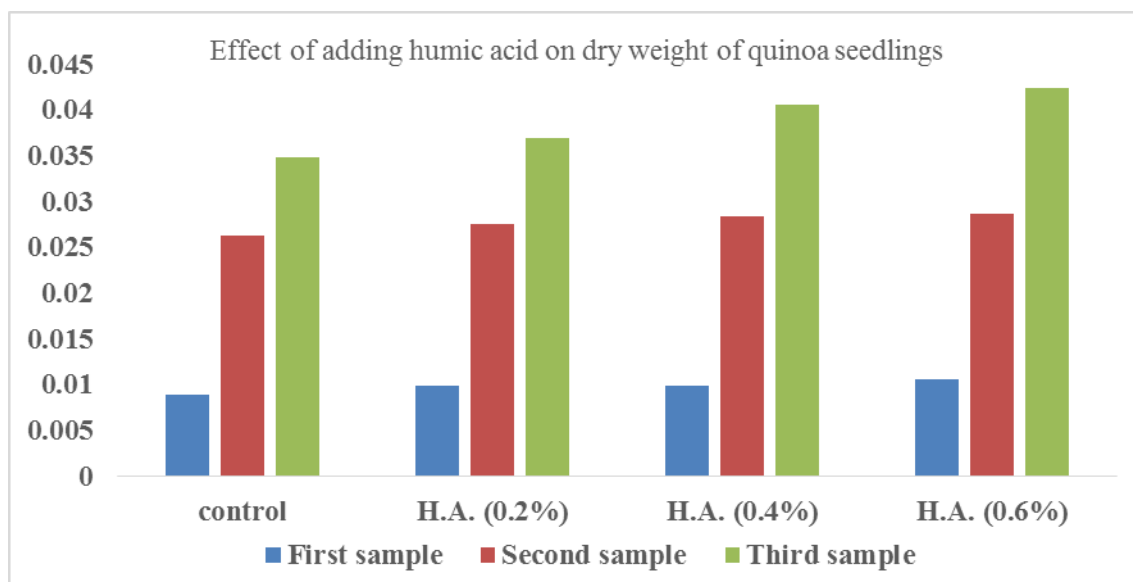


Fig. 8. Effect of adding humic acid on dry weight (gr.) of quinoa seedling at different periods.

Conclusion

The results obtained, the use of humic acid is one way to mitigate the negative effects of salinity, improve natural soil properties, and enhance its fertility. Furthermore, the use of humic acid

improves and increases germination rate, leaf area, and dry matter accumulation in quinoa seedlings. Where it has been shown that quinoa can be grown using saline irrigation water with a concentration of up to 3,000 parts per million, but humic acid should

be added to the soil at a rate of 0.6% to ensure optimal crop performance under the same conditions.

Acknowledgement

The authors would like to sincerely thank all members at Botany Department, Faculty of Science, Derna University, Libya. Undergraduate student Nour El-Huda Suleiman Miftah and Mr. Abdel Razek Ahmed Shahat.

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