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How Does Organic Amendment Improve Quinoa Growth and Productivity under Saline Conditions? †

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Abstract: Nowadays, salinization is becoming a serious problem affecting several agricultural areas, especially irrigated ones. A field experiment was conducted in Foum El Oued, south of Morocco, testing quinoa responses to three irrigation-water salinities (4, 12, and 20 dS/m) combined with nine organic amendments. The obtained results indicate that most of the growth and productivity parameters were negatively affected by salinity, while the effect of organic amendment varied from one salinity level to another. Under high salinity, sheep manure, compost, and insects improved quinoa seed yield by 157, 110, and 83%, respectively, compared to the control. The findings of this study recommend that organic amendment could be a judicious practice to improve quinoa yield under saline conditions.

Keywords: compost; manure; biomass; seed yield; irrigation

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1. Introduction

Agriculture in Morocco is facing several challenges, such as climate change, desertification, water scarcity and salinity, that limit its productivity. Nowadays, salinization is becoming a serious problem affecting several agricultural areas, especially irrigated ones. It is estimated that more than 50% of groundwater in Morocco has an EC value greater than 3 dS/m, causing a decline in crop production; thus, several agricultural areas have already been abandoned due to the salinity problem. Biosaline agriculture can be a judicious solution to bring salt-affected land back to production through the introduction of salt-tolerant and halophytic crops. Crops such as blue panicum, halophytic grasses, quinoa, sesbania, and barley showed great performance, and have already been adopted by farmers [1]. The application of organic amendments is one of the best practices used to cope with salinity and water stress [2]. The objective of this study was to evaluate the impacts of organic amendments and salinity on quinoa growth and productivity.

2. Materials and Methods

This research was conducted on the experimental farm at the National Institute of Agricultural Research in the Foum El Oued area, Laayoune, south of Morocco (latitude:

27.176°; longitude: −13.349°; Z = 37 m). The soil at the experimental site was sandy loam (61% sand, 18% silt, and 18% clay), and was moderately saline and poor in organic matter and nutrients.

Quinoa (*Chenopodium quinoa* Willd.) of the variety ICBA-Q5 was used in this experiment. The area of each plot was 7.5 m^2 and each consisted of five rows with 50 cm between them. The crop was sown manually on 13 April 2021. Crop spacing was kept at 50 cm row-to-row. Irrigation was applied twice a week with an amount of 8.33 mm per irrigation. The irrigation system consisted of drip irrigation with a flow rate of 2 L/h, and the distance between drippers was equal to 20 cm. Three levels of irrigation-water salinity, including 4, 12 and, 20 dS/m, were applied. The low salinity level (4 dS/m) corresponded to the lowest groundwater salinity level in the region. The salinity level of 12 dS/m corresponded to the groundwater salinity level at the experimental site; and 20 dS/m was reached by adding NaCl to low-saline groundwater (4 dS/m).

Nine different organic amendments in addition to a non-treated control were tested, including:

- Cow manure, 30 T/ha;
- Sheep manure, 30 T/ha;
- Goat manure, 30 T/ha;
- Chicken manure, 30 T/ha;
- Compost, 5 T/ha;
- Biochar, 5 T/ha;
- Lombricompost, 5 T/ha;
- Insect frass of *Tenebrio molitor* (mealworm), 5 T/ha; and
- Insect frass of *Hermetia illucens* (black soldier fly), 5 T/ha.

The adopted experimental design was a split-plot design whereby we had two levels of factors; the first level, representing salinity level, was applied in the large plot, and the second level, representing soil amendments, was applied in the sub-plots.

3. Results

3.1. Biomass Accumulation

The effects of irrigation-water salinity and organic amendments on the final fresh and dry biomass are presented in Figure 1. The presented data clearly indicate that biomass was greatly affected by increased salinity. Under high-salinity conditions (20 dS/m) both sheep manure and black soldier fly had the highest biomass accumulation.

3.2. Seed Yield

Figure 2 presents the seed yield variation in quinoa subjected to both salinity and organic amendment effects. It is obvious from the presented data that seed yield decreased with increased salinity. Under high salinity levels (20 dS/m), sheep manure, compost and the insect frass of *Hermetia illucens* showed the highest performances, and improved quinoa seed yield by 157, 110, and 83%, respectively, compared to the control. Under medium salinity levels (12 dS/m), cow manure, the insect frass of *Tenebrio monitor*, and biochar resulted in the highest productivity, and improved seed yield by 44, 38, and 20%, respectively, compared to the control. Under low salinity levels (4 dS/m), the insect frass of *Tenebrio molitor*, chicken, and the insect frass of *Hermetia illucens* showed the highest performance, and increased seed yield by 47, 35, and 31%, respectively, compared to the control. The harvest index was stable under all tested salinity levels, as both biomass and seed yield responded in the same way to both salinity and organic amendment.

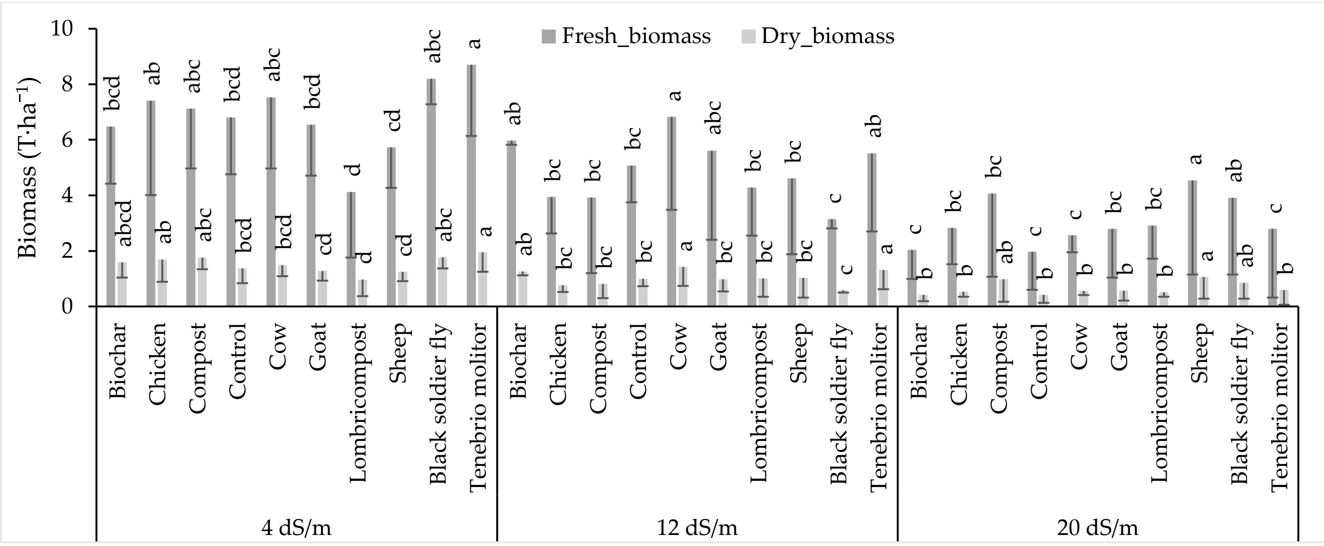

Figure 1. Variation in final fresh and dry biomass as response to irrigation-water salinity and organic amendments. Error bars indicate the standard deviation. a, b, c, and d present Tuckey's test at $p = 0.05$.

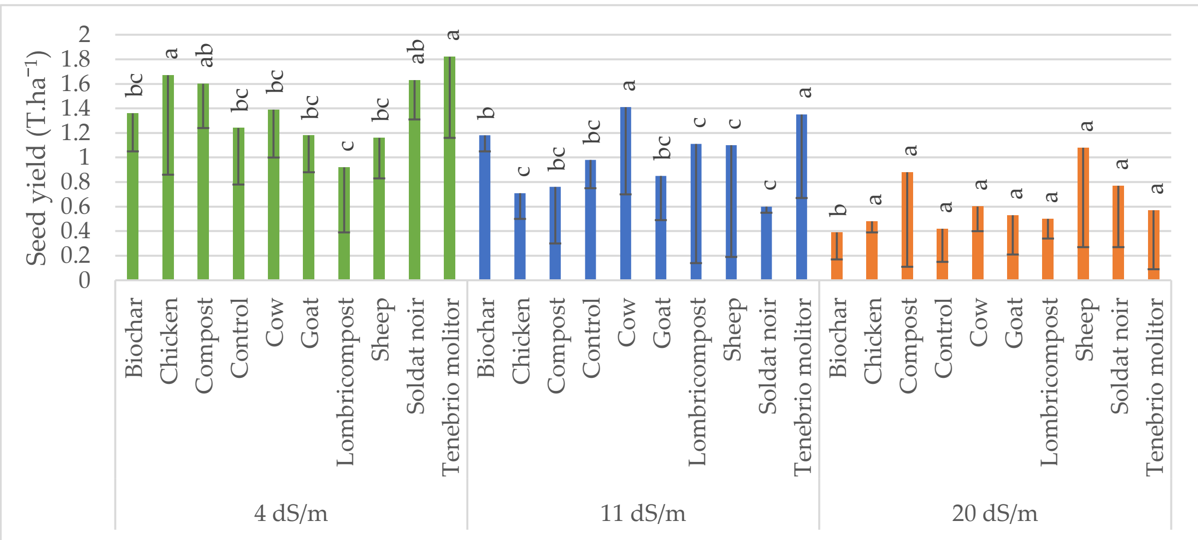

Figure 2. Variation in seed yield as response to irrigation-water salinity and organic amendments. Error bars indicate the standard deviation. a, b, and c present Tuckey's test at $p = 0.05$.

4. Discussion

It is well known that organic amendments can have an important role in alleviating the adverse effects of salinity and drought by improving organic matter content, nutrient availability, water-holding capacity, soil porosity, etc. [3], thus increasing crop productivity. In a similar study testing other types of organic amendment, Alcívar et al. [4] showed that quinoa seed yield in the AZ-51 genotype presented significant increases of 116 and 85% for gypsum and humic substances with gypsum treatments, while biochar had no significant effect on seed yield under saline conditions; this is in agreement with our findings. Similarly, Yang et al. [5] found that the seed yield of quinoa subjected to full irrigation under saline conditions was not affected by biochar amendment, while the latter had a significant effect under deficit irrigation and alternate root-zone-drying irrigation regimes.

5. Conclusions

The findings of this study recommend that organic amendment could be a judicious practice to improve quinoa yield under saline conditions. Furthermore, new organic amendments such as insect frass showed great potential compared to traditional manure.

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Conflicts of Interest: The authors declare no conflict of interest.

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