Responses of Garlic (*Allium sativum*) to Elevated Levels of Salinity and Heavy Metals Presented in the Hackensack Meadowlands

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Introduction

Garlic (*Allium sativum*) is a profitable cash crop species that is valued as an essential flavoring or medicinal herb in a variety of cultures. The rich history of garlic and the awareness of garlic as natural medicine is celebrated in the United States on April 19 of each year as the National Garlic Day. Around 400 million pounds of garlic are produced in US annually, and New York is among the top five producing states.

While garlic is known for its biological elasticity when acclimating to various growth conditions, it requires a steady supply of irrigated water and heavy fertilization to reach marketable size. When high levels of solutes are present in the soil or irrigation, water and nutrient uptake via the roots can be impacted due to elevated osmotic stress, Which, in turn, inhibits garlic growth.

New Jersey Meadowlands, also known as the Hackensack Meadowlands, is a salt marsh located a few miles west of New York City. In addition to high salinity (up to 200 mM), the sediments also contain high levels of heavy metals, including chromium (Cr), Copper (Cu), Zinc (Zn) and Lead (Pb).

In this study, we examined the effects of elevated levels of salt (4 g/L or 68 mM), and copper and zinc (2 mM) on the growth and physiology of garlic. The results indicated stunted growth, damaged leaf and root functions, and disturbed protein metabolism. Overall, our findings emphasized on the impairment of ecological stressors, such as salt and heavy metals, on the life cycle of non-halophytic crop species.

Materials and Methods

Twenty-five garlic cloves were germinated in deionized water and divided into five groups to receive one of the following treatment solutions: 1) Control (di- water); 2) 4 g/L NaCl; 3) 2 mM $CuCl_2$; 4) 2 mM $ZnCl_2$; 5) 1 mM $CuCl_2$+ 1 mM $ZnCl_2$.

The garlic plants were monitored in the greenhouse on campus for three weeks. Every week, the number of leaves, the length of the longest root and longest leaf were measured with a ruler. Leaf photoreceptors (chlorophyll and carotenoids), as well as soluble protein contents in garlic leaf and roots were quantified by colorimetric methods utilizing a spectrophotometer.

Facilities and Instruments

Results

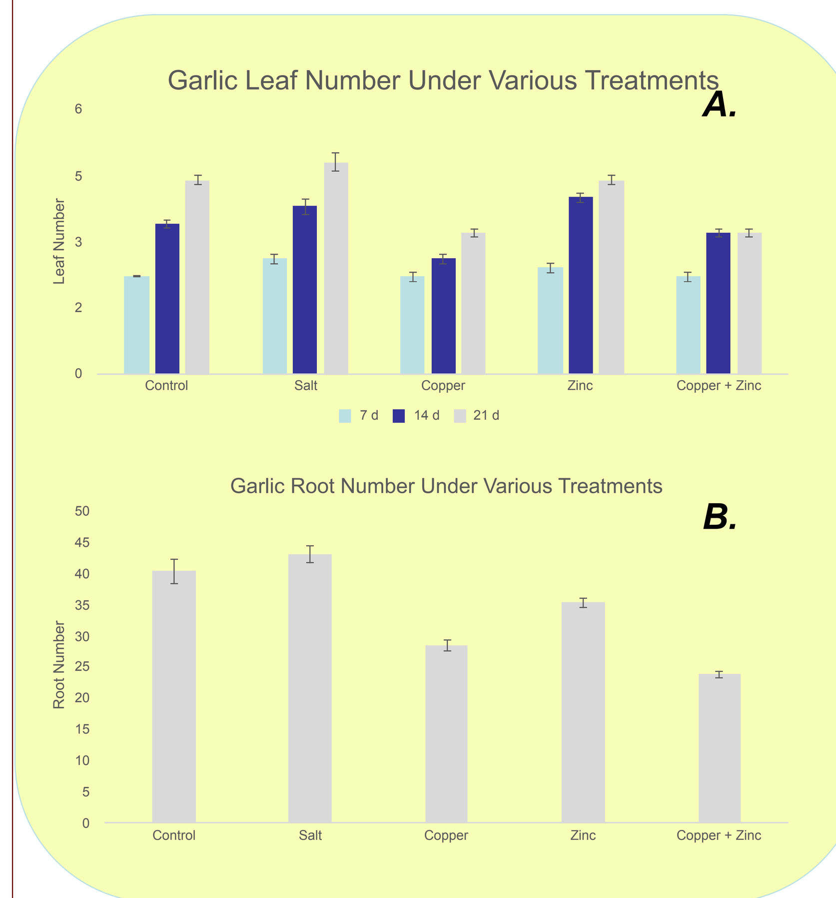
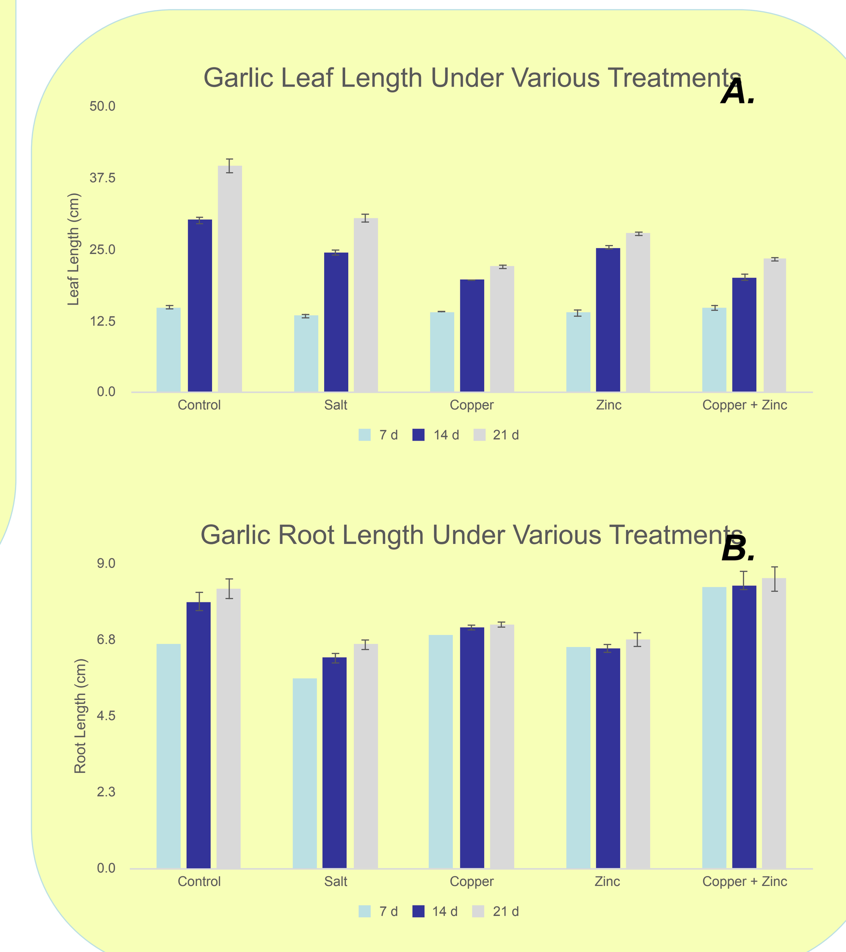


Figure 1 *Leaf (**A.**) and Root (**B.**) Numbers of Garlic Plant Under Various Treatments*

Figure 2 *Leaf (**A.**) and Root (**B.**) Length of Garlic Plant Under Various Treatments*



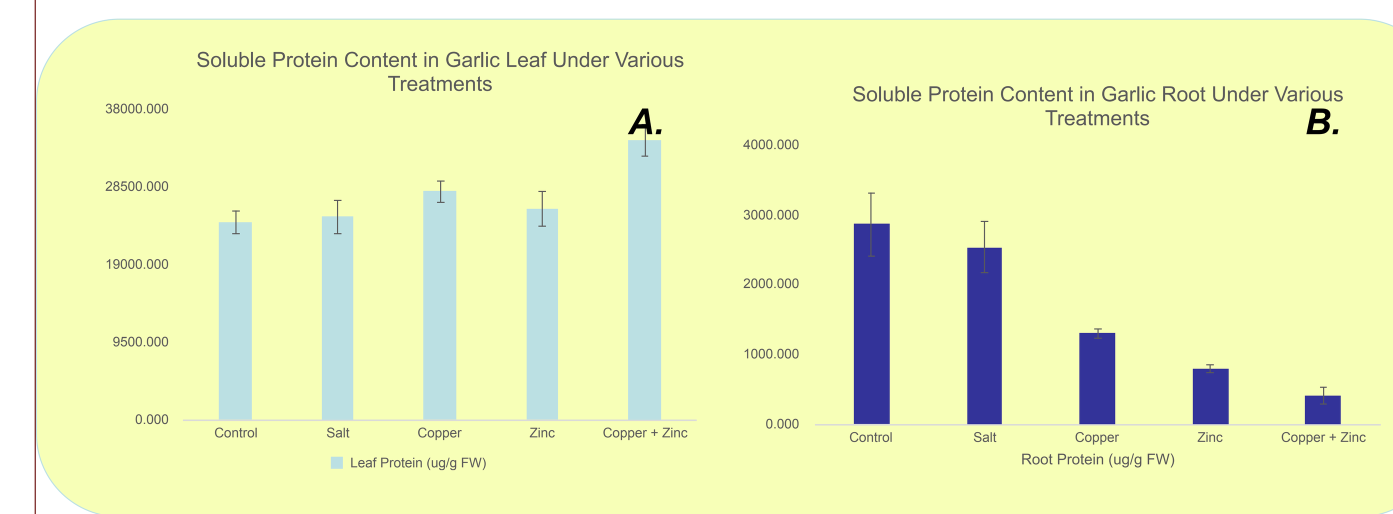
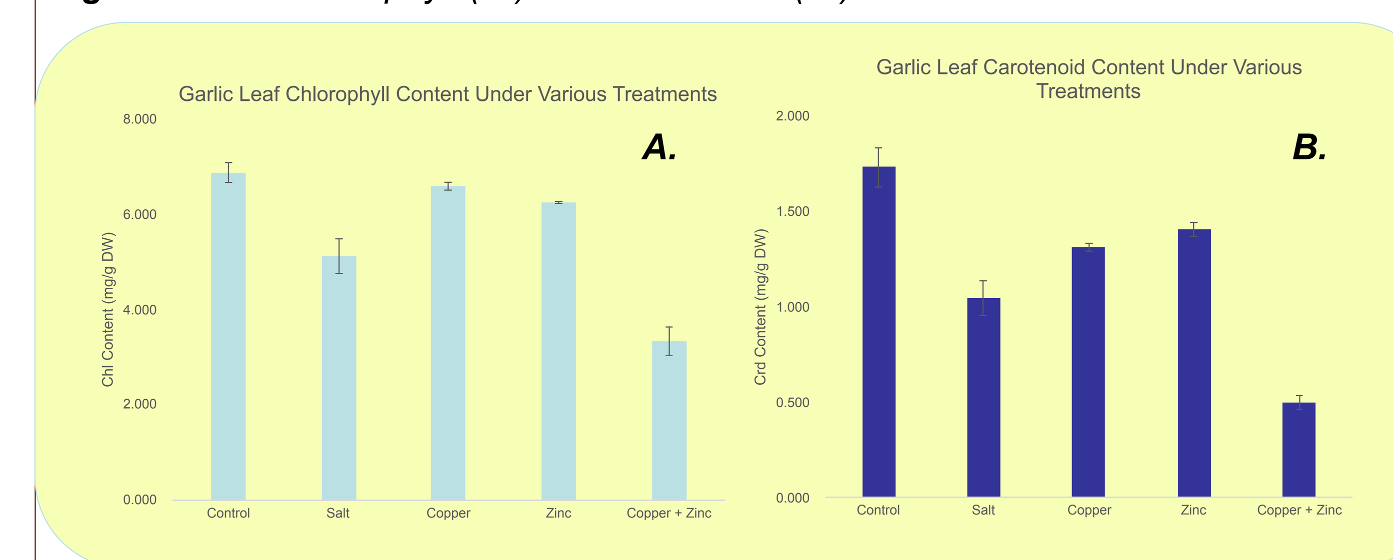


Figure 3 *Protein Content in Garlic Leaf (**A.**) and Root (**B.**) Under Various Treatments*

Figure 4 *Leaf Chlorophyll (**A.**) and Carotenoid (**B.**) Content Under Various Treatments*



Discussion

- New garlic leaves (Figure 1A) were steadily added under control, salt and zinc treatments. Less new leaves were added, and significantly less roots (Figure 1B) were observed in the copper and combined treatments at 21 d.

- Garlic leaves (Figure 2A) grew longer under all treatments; however, the growth was significantly slower in salt and metal treatments after 21 d. A steady growth of garlic roots (Figure 2B) was only seen in the controls, whereas all other treatments inhibited root elongation.

- Salt stress did not affect protein metabolism in garlic leaf and root significantly. Interestingly, the metal treatments significantly damaged root protein production but did not reduce leaf protein production at all (Figure 3A and 3B).

- In fact, the leaf-to-root protein content ratio was 8.5, 9.8, 21.5, 32.3 and 82.6 in the control, salt, copper, zinc and combined treatments. This result indicated that most heavy metals absorbed by garlic roots were accumulated in the roots and was not translocated to the leaves, which might have served as an effective stress avoidance mechanism for garlic plants.

- Salt stress inhibited both chlorophyll and carotenoid production in garlic leaves (Figure 4A and 4B). The inhibitory effect of copper itself or zinc itself is less severe on chlorophyll production than its effect on carotenoid production. As copper and zinc are both essential micronutrients required by plants for photosynthesis, garlic leaves might have mild tolerance to their accumulations. However, the combined treatment led to significant reductions in the production of both photoreceptors, indicating an inevitable disturbance of excessive amounts of heavy metals in garlic leaves.

Summary

- Low salinity (4g/L) did not significantly affect garlic leaf and root growth, though photosynthesis might be more sensitive.
- Copper (2 mM) is sufficient to cause growth inhibition in garlic, as manifested by less new leaves and roots added. Zinc (2mM) had less growth inhibitory effect on garlic than copper (2 mM).
- The combined treatment led to most severe damages in the growth, photosynthesis and protein metabolism of garlic plants, all of which could be related to osmotic and/or oxidative stresses imposed at the cellular and molecular levels.

Future Work

- Test the limits of garlic's salt tolerance with higher salinity levels.
- Conduct additional biochemical and molecular analysis to reveal the mechanisms of garlic plants to cope with harsh environments
- Examine the effects of other heavy metals (lead, cadmium), and their synergistic effects with salt and hormones on garlic plants.

Acknowledgements

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