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Effect of ammonium-clinoptilolite zeolite as a slow- release fertilizer on the growth of bell pepper seedlings (*Capsicum annum L.*)

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INTRODUCTION & AIM

The increasing use of fertilizers and inadequate wastewater management have led to significant nitrate rises in groundwater, threatening its quality and sustainability (Abascal et al., 2021; Bijay-Singh & Craswell, 2021). Nitrate pollution stems from sources like synthetic fertilizers, animal manures, and industrial discharge, particularly affecting shallow groundwater supplies. While surface water treatment is common, groundwater remediation is often overlooked (Abascal et al., 2021). Effective management practices, such as soil-based fertilization and irrigation scheduling, can help control nitrate leaching. Developing low-cost, effective solutions like ammonium zeolite as a slow-release fertilizer is essential for sustainable groundwater management (Sewak et al., 2023).

Zeolites, naturally occurring aluminosilicates, provide significant benefits in agriculture. They can be modified into controlled-release fertilizers, enhancing nutrient efficiency and minimizing environmental pollution (Mihok et al., 2020). By improving soil health and increasing water-holding capacity, zeolites help alleviate heavy metal toxicity (Cataldo et al., 2021). Their porous structure selectively retains essential nutrients like ammonium, phosphate, and potassium, reducing nutrient leaching and improving fertilizer efficiency.

The objective of this study is to evaluate the effectiveness of ammonium-clinoptilolite zeolite as a slow-release nitrogen fertilizer for enhancing the growth of bell pepper seedlings (*Capsicum annuum L.*) under controlled conditions, thereby demonstrating the potential of zeolites in sustainable agriculture.

METHOD

The natural clinoptilolite granulated chip (NCC), obtained from San Luis Potosí, Mexico, was commercialized by Zeomex S.A., a company located in Monterrey, Nuevo León. Standard sieving analysis determined the average grain size (d_{50}) of the clinoptilolite granulated chip to be 2 mm. The clinoptilolite (NCC) was impregnated with NH_4Cl solution in chip and powder forms, referred to as NH_4-ICC (Figure 1(a)) and NH_4-ICP (Figure 1(b)), respectively. The synthesis of NH_4-ECC was carried out using a microwave reactor (Figure 1(c)).

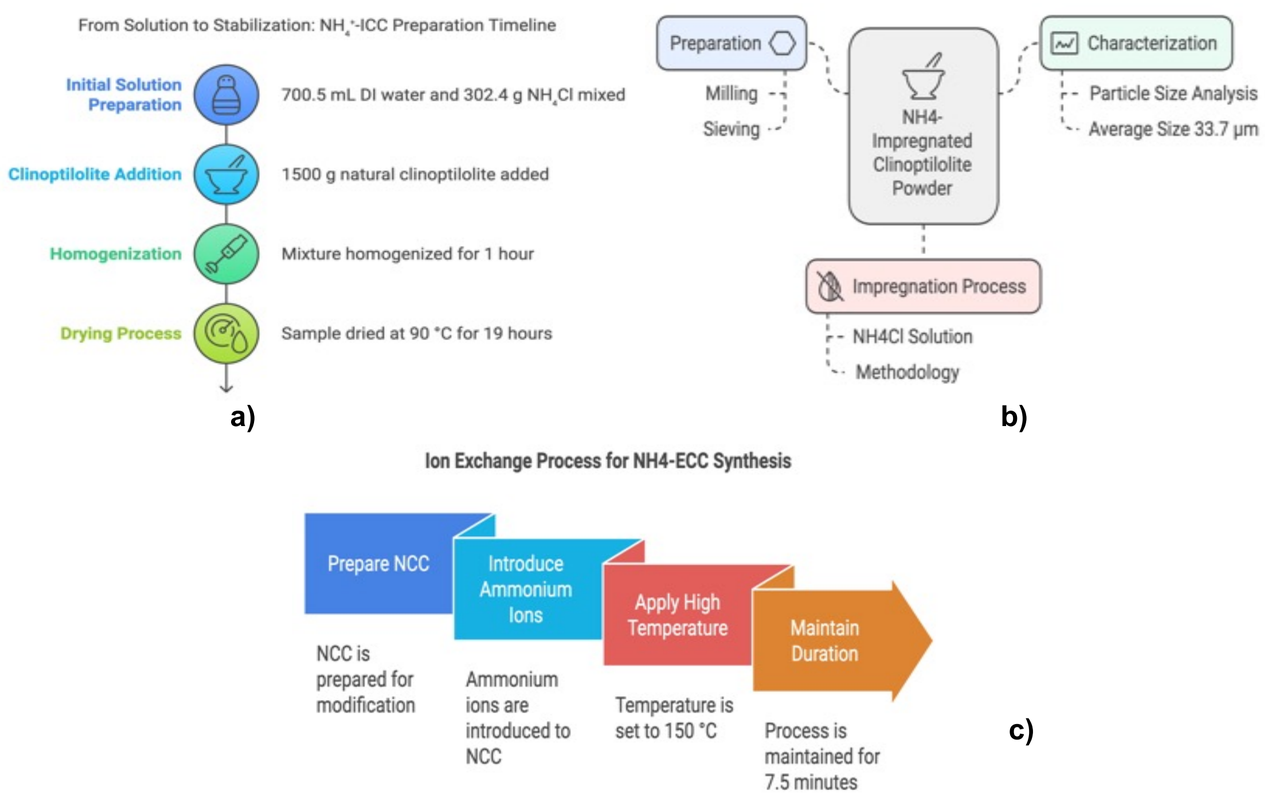

Figure 1: Synthesis Method of NH4+-Clinoptilolite Zeolite: Impregnation in (a) Chip and (b) Powder Forms, and (c) Microwave-Assisted Exchange.

The treatments with zeolite-clinoptilolite were labeled as NH_4-ECC, NH_4-ICC, and NH_4-ICP for T1 to T3, respectively, with the control (T4) receiving synthetic fertilizer based on a Steiner universal solution. The zeolite-clinoptilolite/natural zeolite ratios for T1, T2, and T3 were set at 5%, 15%, and 25% by volume. The effectiveness of these treatments on the germination and growth of bell pepper seedlings (Capsicum annuum L.) was assessed in a greenhouse for 23 days.
Data analysis was performed using R v4.2 with the "ExpDes" package for advanced experimental designs. The experiment employed a completely randomized design with three factors: type of zeolite, ratio of zeolite-clinoptilolite to natural zeolite, and fertilization status. The control group consisted of a conventionally fertilized substrate.

RESULTS & DISCUSSION

Several parameters were analyzed, including plant growth, root length, chlorophyll, leaf number, and dried plant weight. The results revealed a significant increase in plant growth, leaf number, and dried plant weight. Treatments T1C, T1P, and T2P showed high leaf area. The statistical analysis of chlorophyll was not significantly different. However, there was a trend toward increased stem thickness, average number of leaves, plant height, and dried plant weight compared to the control. Similar results indicate that the slow-release capability ensures optimal nutrient availability throughout crop growth, enhancing productivity and quality (Mondal et al., 2021).

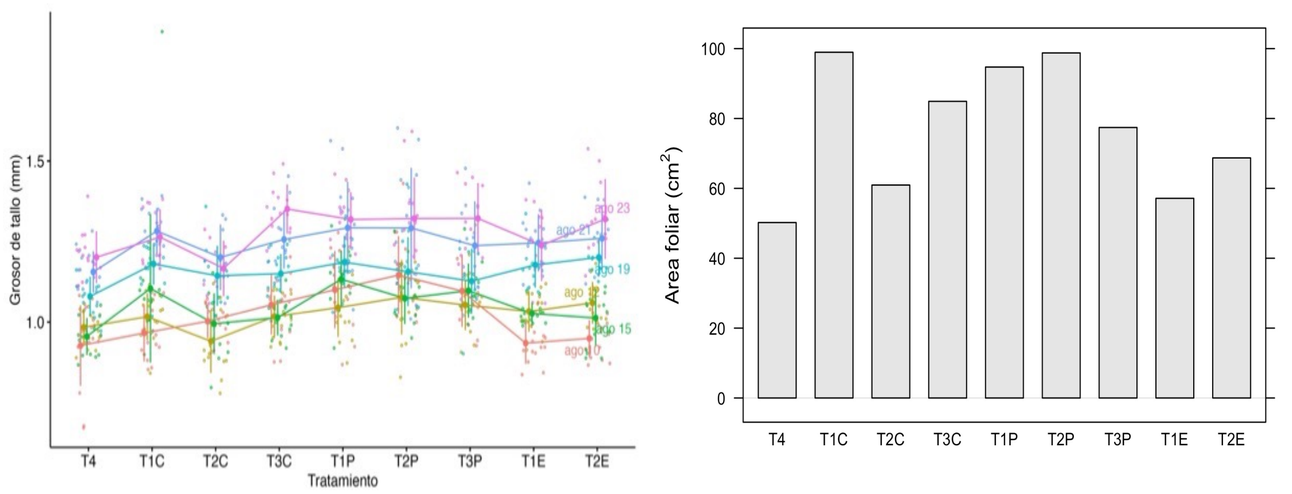

Figure 2: Analysis results of (a) plant growth, (b) leaf area, and (c) chlorophyll.

CONCLUSION

This research highlights the important potential of zeolites as a component of ammonium-based fertilizers. Their ability to minimize nutrient loss and control release makes them a valuable tool for sustainable agriculture.

FUTURE WORK / REFERENCES

Conduct extensive field studies to evaluate the long-term effects of ammonium-clinoptilolite zeolite on various crops in real agricultural settings, assessing its impact on both plant growth and groundwater quality over multiple growing seasons.

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