Terzo Convegno Congiunto Suolo, Pianta, Ambiente - *Sinergie nel sistema suolo-pianta per la tutela dell'ambiente e la sicurezza alimentare,*
Palermo, 12 – 15 Settembre 2023

# Wheat (Triticum aestivum L.) growth performance and nitrogen dynamics in soil amended with ammonium-enriched zeolite from real treated wastewater


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## INTRODUCTION

The increase in world population has led to a demand rise for mineral fertilizers, with a consequent boost in chemical production [1]. Nitrogen (N) plays a key role in global food production, being an essential macronutrient for plant growth [2]. Wastewater holds many organic and inorganic compounds, often containing nitrogen and phosphorous, i.e. main plant nutrients [3]. Porous materials, such as zeolites, are considered very suitable for wastewater treatment and nutrient adsorption [4]. One potential application is the use of natural zeolites to remove nutrients such as $NH_4^+$ from wastewater, thus reducing the risk of eutrophication of the aquatic environment and reusing the $NH_4^+$ enriched zeolite as a slow-release fertilizer [5].

## AIM OF THE STUDY

This study evaluated the effect of ammonium-enriched zeolite ($NH_4^+$) as a slow-release fertilizer for wheat cultivation. The zeolites used were equal in mineralogy but with different particle sizes (T3 ø 0.5-1.0 mm and T4 ø 2.5-5.0 mm). The T3 and T4 zeolites were previously enriched in filter columns located in a pilot wastewater treatment plant using real wastewater from the Water Resource Recovery Facility at the University of Palermo [5]. The amount of $NH_4^+$ supplied with fertilizer or enriched zeolite was 30 mg N per plant. The experimental test was carried out over a period of 88 days.

## MATERIALS & METHODS

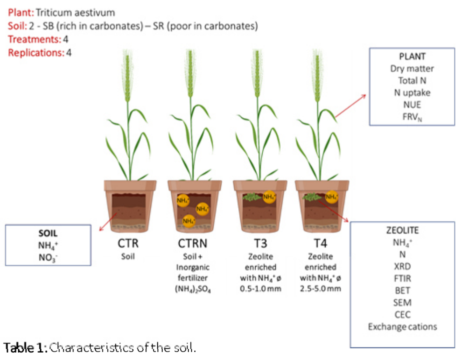


**Table 2.** Elemental composition (%) of the tested zeolites and mineralogical composition of tested zeolites determined with XRD analysis. The reported results are mean ± standard deviation of four replicates.

| Element (%) | |
|---|---|
| Oxygen | 70.6 ± 1.2 |
| Silicon | 16.9 ± 0.7 |
| Aluminium | 4.1 ± 0.2 |
| Si/Al | 4.2 ± 0.2 |
| Si/O | 0.24 ± 0.01 |
| Al/O | 0.06 ± 0.00 |
| Heulandite | 47 |
| Mordenite | 20 |
| Clinoptilolite | 17 |
| Stellerite | 16 |

**Table 1:** Characteristics of the soil.

| Soil | pH | Electrical Conductivity | Organic Carbon | $CaCO_3$ | Active Carbonate | $NO_3^-$ | $NH_4^+$ | TN | Olsen P | Cation Exchange Capacity |
|---|---|---|---|---|---|---|---|---|---|---|
| | | µS cm$^{-1}$ | | % | | mg kg$^{-1}$ | | % | mg kg$^{-1}$ | cmol kg$^{-1}$ |
| SB | 8.51 | 138.8 | 0.68 | 47.2 | 9.63 | 65.17 | 5.40 | 0.080 | 6.41 | 9.65 |
| SR | 7.61 | 131.3 | 0.51 | 6.8 | 2.28 | 60.20 | 8.68 | 0.078 | 8.54 | 10.33 |

## RESULTS

The amount of KCl-exchangeable $NH_4^+$ in the soil following the application of the inorganic fertilizer (CTR+N) increased in both SB and SR soils. The application of $NH_4^+$ T3-enriched zeolite showed in absolute values an increase, especially when applied to SB, with values equal to or greater than the values obtained with inorganic fertilizer. The application of $NH_4^+$ T4-enriched zeolite showed intermediate values between the unfertilized control (CTR) and the control with fertilizer (Figure 1).
The average plant dry matter value was always higher in SB than in SR. The addition of $NH_4^+$ enriched zeolites increased the dry matter of the plants, achieving the same results as inorganic fertilizer (Figure 2).

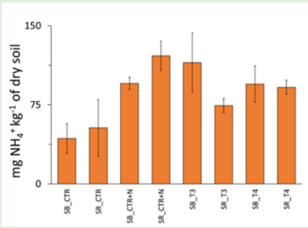


**Figure 1:** Effect of the different fertilizer treatments on exchangeable $NH_4^+$ in soil after wheat harvesting. Values are mean ± standard deviation of four replicates.

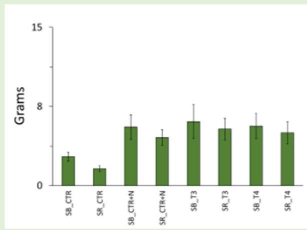


**Figure 2:** Effect of fertilizer treatments on total dry matter yield of wheat plants. Values are mean ± standard deviation of four replicates.

The input of the inorganic fertilizer showed a significant increase in grain yield only when applied to SR soil. The application of $NH_4^+$ enriched zeolites showed a significant increase in grain yield compared to both CTR and CTRN (Figure 3). The N uptake reflects the results obtained in the total dry matter and grain yield already shown. The application of inorganic fertilizer significantly increased N uptake compared to the unfertilized control, in both soils. The application of $NH_4^+$ enriched with zeolite showed an increase in N adsorption equal to that obtained with inorganic fertilizer. (Figure 4). The Nitrogen Use Efficiency (NUE) showed no significant differences between inorganic fertilizer and $NH_4^+$ enriched zeolites. The Fertilizer Replacement Value ($FRV_N$) increased when $NH_4^+$ enriched zeolites were applied, particularly by T4-zeolite in SR soil. The application of $NH_4^+$ enriched zeolites resulted in a fertilizer replacement value ranging from 60% to 93% (Figure 5B).

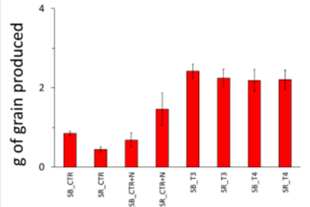


**Figure 3:** Total amount of grain produced. Values are mean ± standard deviation of four replicates.
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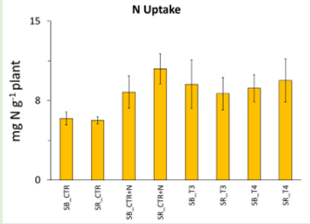


**Figure 4:** Effect of fertilizer treatments on N uptake of wheat plants. Values are mean ± standard deviation of four replicates.

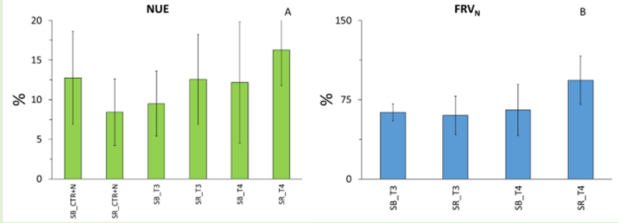


**Figure 3:** Total **Figure. 5 (A and B):** A) Nitrogen Use Efficiency and B) Nitrogen fertilizer replacement value on a N uptake basis for the different n fertilizers. Values are mean ± standard deviation of four replicates.

## CONCLUSIONS

1. Inorganic fertilizer and $NH_4^+$ enriched zeolite both increased KCl-exchangeable $NH_4^+$ levels, with zeolite outperforming in SB soil (Figure 1).
2. $NH_4^+$ enriched zeolites matched the effects of inorganic fertilizer in increasing plant dry matter, grain yield, and N uptake (Figures 2, 3, and 4).

## FUNDS


This work was funded by the project "Achieving wider uptake of water-smart solutions—WIDER UPTAKE" (grant agreement number: 869283) financed by the European Union's Horizon 2020 Research and Innovation Programme. Website https://wideruptake.unipa.it/, https://www.sintef.no/projectweb/wider-uptake/


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