

INDUCTION OF PLANT IMMUNE RESPONSES BY NATURAL ZEOLITES: INSIGHTS INTO DEFENCE SIGNALLING PATHWAYS

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More Information:

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Introduction

Due to climate change there is a growing demand for sustainable and environmentally friendly technologies that support plants while maintaining or improving crop production [1, 2].

Among the numerous biostimulants and/or fertilizers, natural zeolites are widely used to enhance crop growth and yield because of their high cation exchange capacity and strong affinity for soil nutrients and water [3]. Increasing evidence also suggests that foliar application of zeolites can serve as a potential tool to mitigate various stresses such as drought [4, 5, 6] and heat stress [7, 8]. However, fundamental questions about how natural zeolites regulate these processes remain unanswered. This study aimed to identify the molecular signalling events triggered by foliar application of clinoptilolite-based minerals and investigate how these components promote long-term defence responses in plants.

Treatments

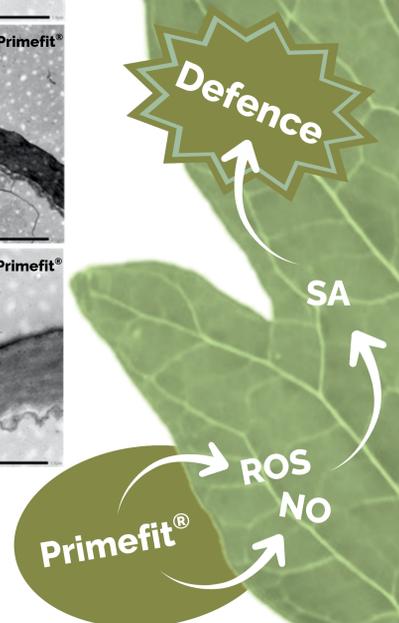
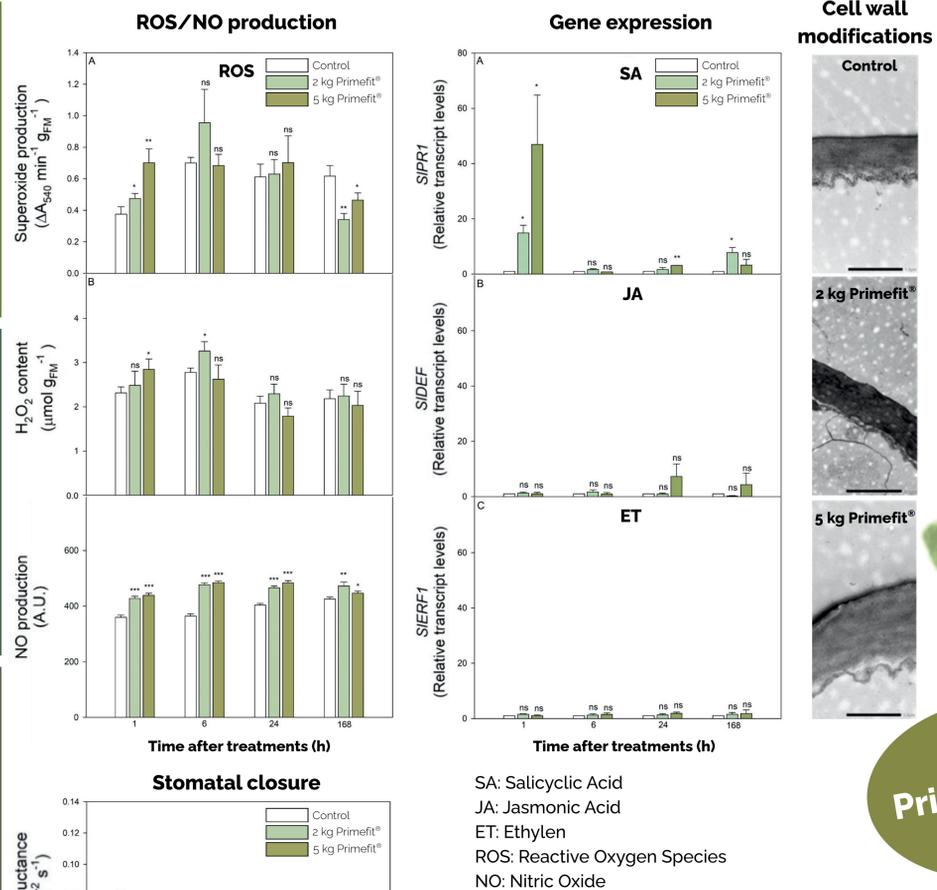
- 2023 (lab): Tomato plants in nutrient solution according to Poór et al. [9].
- 2024 (field): Apples and Potatoes, Bordány (Hungary).
- Foliar spray in both experiments: 2 and 5 kg/200L/ha of Primefit[®] suspension in sterilised water
- Control: sterilised water

Material Used

The natural mineral used in this study (Primefit[®]) is a thermo-physically activated clinoptilolite-zeolite blend, enriched with essential cations (Ca, K, Mg). Its micronized particle structure enhances surface reactivity and interaction with leaf tissues, facilitating the activation of endogenous defence signalling pathways.

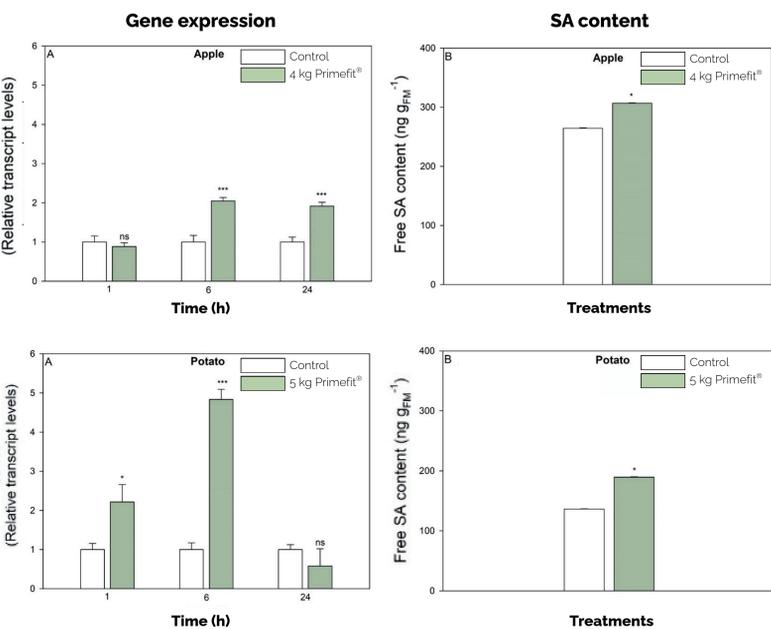
Methods

- Superoxide (O₂⁻), hydrogen peroxide (H₂O₂) content (both ROS): spectrophotometer
- Nitric oxide (NO) production: fluorescence microscope
- Stomatal conductance: gas exchange analyzer
- Cell wall structure: electron microscope
- Gene expression: quantitative real-time PCR Salicylic acid (SA) content: HPLC



Conclusions

- Application of the clinoptilolite-zeolite blend increased O₂⁻, H₂O₂ and NO production within the first hour in tomato leaves contributing to sublethal oxidative stress in the plants initiating defence activation.
- ROS and NO accumulation caused rapid stomatal closure, which recovered after 24 hours.
- One week after the application, thickening of cell walls was observed in tomato leaves.
- Application of the clinoptilolite-zeolite blend rapidly increased the transcript levels of SA marker gene PR1 in tomato leaves.
- The clinoptilolite-zeolite blend induced SA accumulation and PR1 expression within six hours in the leaves of apple and potato plants contributing to the activation of systemic defence, vitality plants, and higher yields in these species.
- Our results clearly demonstrate the mode of action via SA signalling in plant leaves, suggesting its effective applicability in environmentally friendly and sustainable agriculture.



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