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Making a New Hybrid Calcium Mineral Colloid for Plant Development and Defensive Responses

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ABSTRACT

Worldwide, there is a rising demand for food. So it is imperative to enhance crop yields and the area that may be used for crop production. Macro, micro, and nanoparticles have been used in agriculture to produce crops sustainably. The creation of synthetic particles is crucial to crop management. We created an innovative calcium-based Si hybrid mineral to increase the effectiveness of mineral delivery to plants. Arabidopsis culture was used to test this material's ability to transport minerals. According to analysis of the hybrid mineral, it comprises ca2+, si, and carbonate sources, all of which are beneficial for boosting crop yields and defending plants from infections. Thus, by playing crucial roles in numerous plants metabolic processes, this unique Caco3-Casi hybrid mineral act synergistically on Arabidopsis root growth and confers resistance to bacterial diseases, increasing crop production and protection.

Keywords: Plant growth, Plant resilience, Hybrid Calcium mineral, Calcium silicate, and Calcium carbonate

INTRODUCTION

Ca^{2+} is a crucial mineral nutrient for living things and is the fifth-most prevalent element on earth by mass. It is essential to many different cellular and physiological processes. Ca^{2+} signaling plays a role in immune response, stress response, and developmental processes in plants. For biotic stress defence, plants have developed a two-layered immunological signaling mechanism. Pathogen-associated molecular patterns that trigger immunity make up the first layer. This is a fundamental defence that starts a chain of events that results in downstream reactions including stomatal closure and the production of defence genes at the infection site. One of the early PTI responses is Ca^{2+} signaling. Effector-triggered immunity, which involves programmed cell death at the site of infection, is the second line of defence. In ETI, Ca^{2+} signaling also contributes. Ca applied exogenously also increases plant biomass and postpones senescence. Ca has been extensively researched for its protective function in plant responses to drought, cold, and oxidative stress as a second messenger. Application of Ca has been shown to increase plant biomass, biotic stress resistance, and abiotic tolerance in previous research.

Additionally, si has been demonstrated to lessen biotic and abiotic stressors in plants. Si can reduce stress caused by K insufficiency by raising the amounts of antioxidants and chlorophyll. Si can also boost photosynthesis and reduce cellular oxidation. Si also improves plant defenses against viral, bacterial, and fungal illnesses as well as insect pest infestation. Si builds up in plants in this situation, forming a physical barrier. Due to the development of a Si layer on the leaf cuticle, it has been observed that the presence of Si in hydroponic rice cultures considerably reduces Pyricularia grisea penetration in rice leaves. Additionally, in tomatoes infected with Erysiphe cichoracearum, Si can stimulate the signaling pathways for ethylene and jasmonic acid. The latter is better for plant nutrition since it offers important elements like Ca and Si. Ca_2SiO_4's Si content can increase stem strength, delay wilting in some crops, and improve drought tolerance. Silicate solutions, on the other hand, significantly raise pH since they are alkaline. Thus, their application may result in high soil pH, which reduces the availability and solubility of nutrients and adversely impacts plant growth. To use Si as a mineral fertilizer, soil acidification is necessary to lower the pH of the soil and the negative impacts it have on crop production and financial returns. A different acidifying mineral fertilizer is CaCO3, which lowers pH by releasing H^+ during decoThe thermal stability of NH_4NO_3 in fertilizers used as effective sources of N in plant culture can also be improved by the CO_3 generated by $CaCO_3$, which is another benefit. Plant growth has improved significantly as a result of the addition of these mineral components to soils. By increasing the root's surface area and lengthening the root system, the favorable effect of nutrient uptake in native soils aids in overcoming nutritional constraints and increases access to additional nutrient sources. However, there is ongoing debate in the scientific community about whether minerals serve as nutrients for plant growth.

In this study, we looked at how an unique synthetic Ca-based Si mineral affected plant development and defence mechanisms. We describe the production of a hybrid Ca mineral by two consecutive bio mineralization stages, namely the creation of Ca2SiO4 particles and the covering of the Ca_2SiO_4 surface with $CaCO_3$. Compared to pure Ca_2SiO_4 or $CaCO_3$, these two independent crystallizations provide distinct physical and chemical features.

The Emmett-Teller surface area, pore volume, adsorption/desorption pore size, scanning electron microscopy, and particle size investigations were used to evaluate the attributes of the new Ca-based Si hybrid mineral in terms of its distinct structure, surface area,

morphology, and particle size. The material was also characterized using X-ray diffraction studies and Fourier-transform infrared spectroscopy. This research offers a fresh viewpoint on Ca-based Si mineral hybrid materials that may enhance plant development and defence mechanisms.

RESULTS AND DISCUSSION

Hybrid Ca minerals' creation and characterization

Ca_2SiO_4 mineralization, followed by $CaCO_3$ precipitation to coat the surface, was used to successfully create hybrid Ca minerals. Sodium silicate and $CaCl_2$ were forcefully combined in water at room temperature to create the Ca_2SiO_4 crystals. In a prior study, hard surfaces were coated with $CaCO_3$ to show how the deposition varied depending on the surface type and orientation. In this work, Ca-SiO2 minerals were employed as the base materials for an additional $CaCO_3$ coating to be applied to the Ca_2SiO_4's surface in order to give additional functionalities that may have a major impact on grain yield and dry matter. Si appears to have a positive impact on stressed plants in plant cultivation. It can increase stem strength, drought tolerance, and resistance to micronutrient and other metal toxicity. Utilizing SEM, EDS PSA, BET, BJH adsorption/desorption, XRD, and Ft-Ir, the synthesized hybrid Ca mineral was satisfactorily characterized. According to the SEM investigation, the aggregated morphology adopted two mixed crystal structures. The size distribution of the hybrid Ca mineral was wide. The characteristics of the $CaCO_3$-coated silica surface were verified using EDS. The corresponding Ft-Ir spectrum also served to further support the $CaCO_3$ coating on Ca_2SiO_4.

Exogenous Caco3-casi hybrid mineral improved the growth and bacterial pathogen resistance of arabidopsis

Ca is a vital plant element that is frequently added to fertilizer solutions to promote plant growth and disease resistance. $CaCO_3$ can improve plant nutrition while reducing Botrytis blight symptoms in grapes. We ran an assay on Arabidopsis plants to see if the $CaCO_3$-CaSi hybrid micro particles may have an impact on plant growth. As anticipated, the hybrid $CaCO_3$-CaSi micro particles greatly increased root development when compared to media. This suggests that the hybrid $CaCO_3$-CaSi micro particles may promote plant growth.

We developed a novel kind of $CaCO_3$-CaSi micro-particle based on the findings of our prior research and looked at how these particles affected Arabidopsis plants. On plant growth and defence, the $CaCO_3$-CaSi micro-particles showed favorable benefits. The use of this Ca-based Si micro-particle as a delivery mechanism for crop plants will be our next goal. According to earlier research, one of the most important characteristics of Ca minerals is their high capacity for loading organic molecules including active substances, medicines, proteins, and enzymes. To regulate nucleus growth and crystallization during the mineralization route, organic molecules can be utilized as templates. To the best of our knowledge, this is the first account of a hybrid mineral-based micro-particle entity that has application in agricultural science and enhances plant growth by providing Ca and Si.

CONCLUSION

To our knowledge, this is the first study to highlight the potential application of synthetic hybrid minerals for mineral delivery to promote plant root growth and resistance to bacterial infections. SEM was used to successfully prepare and characterize Ca-based Si micro particles. This hybrid mineral is used in agriculture to boost plant yields and provide disease defence. Modern agriculture needs to be more sustainable and should guarantee that everyone has access to healthy food in the current climate of environmental change and rising population pressure. Ca-based Si micro-particles seem to offer potential as a fertilizer for agricultural development. Additionally, this innovative technique offers prospective delivery vehicle systems in agricultural as well as Ca and Si, which are active elements for crop protection.