Researchers Achieve Efficient Nutrient Delivery to Crop Leaves through Nanomaterial Surface Roughness Engineering

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Researchers have used surface roughness engineering of silicon-based nanomaterials to achieve efficient delivery of essential nutrients to crop leaves.

Researchers led by Prof. WANG Guozhong and ZHOU Hongjian from the Hefei Institutes of Physical Science (HFIPS) of the Chinese Academy of Sciences (CAS) have used surface roughness engineering of silicon-based nanomaterials to achieve efficient delivery of essential nutrients to crop leaves. Their findings, published in ACS Nano, reveal a new strategy for maximizing nutrient uptake in crops.

Conventional soil fertilization involves applying nutrients to the soil, whereas foliar fertilization allows nutrients to be sprayed directly onto the leaf surfaces of crops. This allows the nutrients to participate directly in the crop metabolism and organic matter synthesis. However, due to the lotus leaf effect on crop leaves, foliar nutrients often slip off during spraying or are washed away by rain and end up in the environment. Therefore, a solution was needed to develop a fertilizer technology that could efficiently adhere to hydrophobic leaf surfaces.

In this study, the researchers addressed the instability of certain fertilizers during application, such as the oxidation of the iron element Fe(II) to Fe(III), which is difficult for plants to absorb. They developed a pH-controlled oxidation-resistant ferrous foliar fertilizer (ORFFF) delivery system using environmentally friendly silicon-based micro/nanomaterials as carriers.

By incorporating vitamin C as an in-situ antioxidant, the system alleviates iron deficiency in crops and increases crop yield. The unique hollow structure and dense cross-layered nanosheets of the ORFFF enable it to possess excellent iron antioxidant capacity, high leaf adhesion efficiency, slow-release nutrient capability, and exceptional rainfastness on plant leaves.

Morphology of sea urchin-shaped hollow silicon-based foliar nitrogen fertilizers.

In recent years, the researchers have used surface roughness engineering with nanosilica to create three new types of foliar nitrogen fertilizers with different surface shapes: solid, hollow, and sea urchin-shaped. Compared to typical foliar nitrogen fertilizers, these nanostructured fertilizers exhibited significantly higher adhesion to peanut and corn leaves, with adhesion abilities 5.9 times and 2.2 times greater, respectively. Corn seedlings treated with the nanostructured fertilizers showed a 2.3-fold improvement in nitrogen utilization. The micro-nano structure and high surface roughness of the carriers optimize their properties and improve the wettability and adhesion of the fertilizer to the crop leaves.

The novel pH-controlled environmental self-adapting PMFF have super-high foliar adhesion ability and high rainfastness property.

To address magnesium deficiency in modern agriculture, the researchers also developed a foliar magnesium fertilizer called Pompon-like Magnesium Foliar Fertilizer (PMFF). Using an ammonia-assisted sacrificial nanosilica template, they incorporated the nutrient element magnesium directly onto the nanosilica template. The release of magnesium from PMFF could be controlled by adjusting the pH of the solution during fertilization to meet the magnesium requirements of different crop growth stages. Tomato seedlings treated with PMFF showed a magnesium consumption rate 9.0 times higher than that of standard foliar magnesium fertilizers.

Digital photographs of tomato seedlings in different growth periods ((a) before fertilizer spraying, (b) after simulating twice rain washes, (c) harvest) sprayed with deionized water, TFFF, Fe(III)/SiO_2, and ORFFF solution.

These innovative results provide a viable approach to using smart engineered nanomaterials to facilitate the effective delivery of nano-agricultural fertilizers, offering new opportunities to improve crop nutrition and productivity.

Read the original article on Chinese Academy of Sciences (CAS).