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Mesoporous silica-based nanocarrier platform to deliver Zn as micronutrients to plant crops

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Foliar application of nanocarrier-encapsulated micronutrients offers a promising strategy to enhance crop productivity while mitigating the adverse environmental impacts of conventional soil application of fertilizers, such as soil and water quality degradation. However, the uptake, translocation and fertilization efficiency of fertilizer nanoparticles is often limited . To address such limitations, we designed a mesoporous silica nanocarrier (MSN) for controlled and sustained release of encapsulated fertilizers. In this study, we encapsulated ZnO nanoparticles in the MSN (ZnO@MSN) for delivering Zn as a micronutrient to tomato plants (*Solanum lycopersicum*) via foliar application. Over a 5-day growth period, MSN enhanced Zn uptake by 180% compared to bare ZnO nanoparticles while eliminating leaf scorching observed with traditional soluble Zn fertilizers.[1] Furthermore, our study suggests that the translocation efficiency increased by 56% when ZnO@MSN was applied to the abaxial (lower) leaf surface versus the adaxial (upper) side, correlating with higher stomatal density on the abaxial surface.[2] For the first time, Time-of-Flight Secondary Ion Mass Spectrometry (ToF-SIMS) imaging of tissue cross-sections confirmed the phloem-based translocation pathway of core-shell structured nanomaterials from the dosed leaf.[2] These findings highlight MSN as a novel, sustainable platform for precision delivery of agrochemicals, with the potential to reduce fertilizer use, minimize environmental contamination, and improve crop resilience.

[1] Uptake and translocation of mesoporous SiO2-coated ZnO nanoparticles to Solanum lycopersicum following foliar application. Gao, X., Kundu, A., Bueno, V., Rahim, A. A., & Ghoshal, S. (2021). *Environmental Science & Technology*, *55*(20), 13551-13560.

[2] Application of ZnO nanoparticles encapsulated in mesoporous silica on the abaxial side of a Solanum lycopersicum leaf enhances Zn uptake and translocation via the phloem. Gao, X., Kundu, A., Persson, D. P., Szameitat, A., Minutello, F., Husted, S., & Ghoshal, S. (2023). *Environmental Science & Technology*, *57*(51), 21704-21714.