Researchers formulate controlled delivery of micronutrients to promote plant growth

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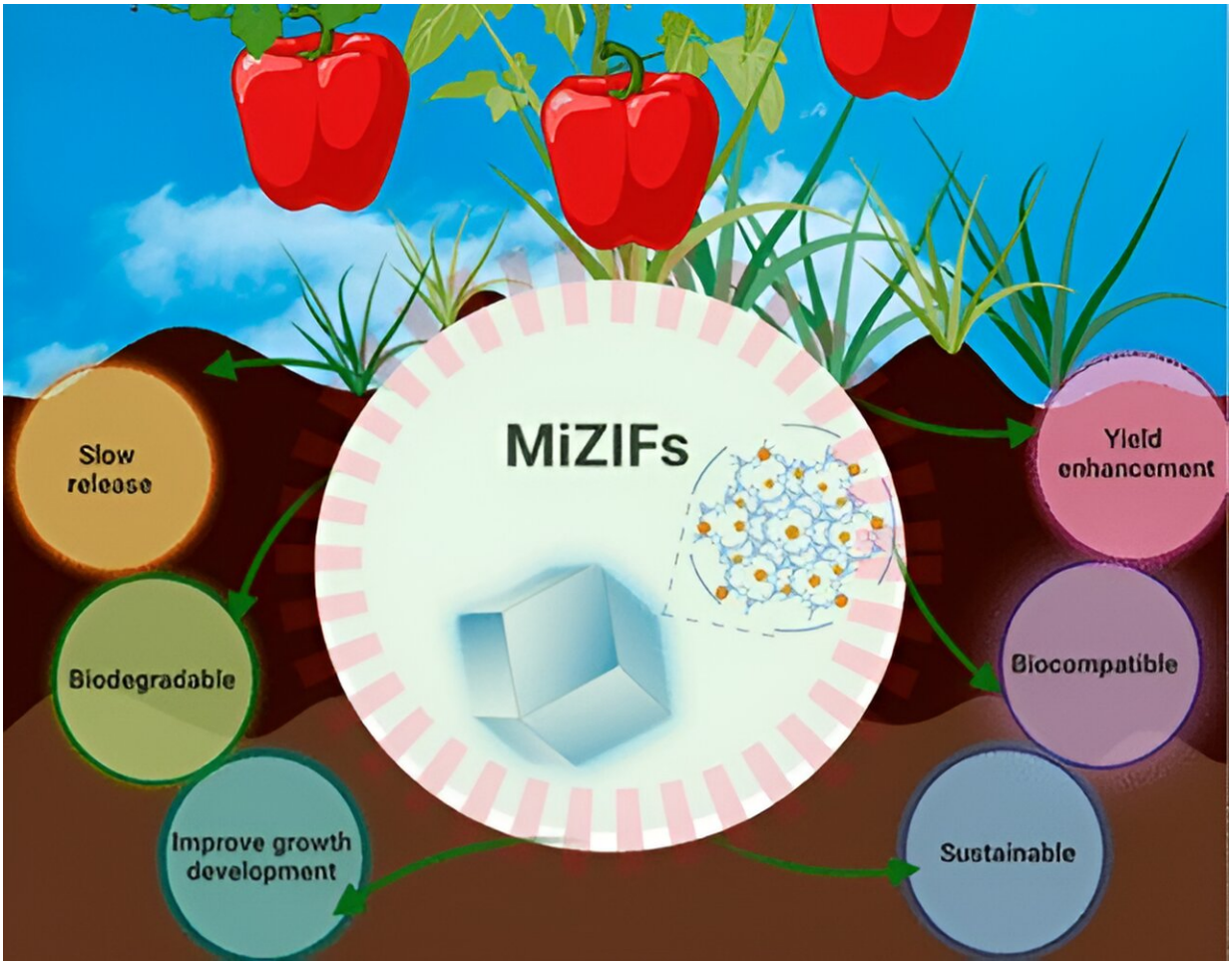

Graphical abstract. Credit: *Nano Letters* (2023). DOI: 10.1021/acs.nanolett.2c04506

Improvements in crop productivity and nutritional value are needed to meet increased global demand for food in terms of both quantity and quality. A strategy being investigated by KAUST researchers to address the issue is the controlled delivery of bioactive molecules, such as growth-stimulating compounds and micronutrients that can be stored in fruits or grains to stimulate stress tolerance and enhance crop yield and resistance to pathogens.

"There is a clear demand to develop smart platforms for the precise and controlled delivery of agrochemicals," says KAUST plant scientist Salim Al-Babili.

"As well as the encapsulation of fertilizers, there is also a need to encapsulate and deliver minerals that act as human micronutrients, such as zinc, to improve the nutritional value of crops."

A cross-disciplinary team, led by Ph.D. student Katya Perez and postdoc Yagiz Alagoz, has developed a new formulation for the smart delivery of a synthetic mimic of the growth regulator zaxinone (MiZax-3), which promotes plant growth with proven growth stimulant activity. Their research is published in the journal *Nano Letters*.

Biomimetic mineralization using zeolitic imidazolate frameworks (ZIFs) is a widely used method for encapsulating a range of chemicals, from small hydrophobic molecules to large hydrophilic proteins.

"Over the past decade, we have developed a range of stimuli-responsive platforms that can encapsulate an impressive variety of cargo, ranging from neutral small chemicals to charged high-molecular-weight biologics," says Khashab.

The researchers used the zinc-containing ZIF-8, a nano-scale metal-organic framework (MOF) that can efficiently load MiZax-3 as a

platform, while keeping it stable at high temperatures, under real-life field conditions, and releasing the MiZax-3 load in a pH-dependent way.

Material scientist Katya Pérez and plant scientist Yağız Alagöz collaborated to develop new smart materials to improve precision micronutrient delivery to crops. Credit: KAUST

They initially tested the new formulation, which they named MiZIFs, in a small-scale experiment by applying it to tomato and pearl millet seedlings in hydroponic media. The application of MiZIFs enhanced the fresh weight of tomato and pearl millet seedlings, indicating that the MiZIF complex can effectively release bioactive MiZax-3, which

promotes plant growth at the early seedling stage.

Perez notes the importance of developing new smart materials that are easy to scale up for precision micronutrient delivery. "The MiZIFs platform gave us the opportunity to do more translational research," she explains.

The encouraging findings prompted the team to assess growth-promoting efficiency of MiZIFs under field conditions by performing a small-scale field trial with capsicum. Seedlings treated with MiZax-3 and MiZIFs had a significantly higher number of flower buds than the control. In addition, the ZIF-8, MiZax-3 and MiZIFs treatment significantly enhanced plant height observed at six and eight weeks after the first treatments and increased the yield recorded at two consecutive harvests compared to the control.

The researchers hypothesized that the Zn ions in the framework (the coordinating ions) were contributing to the enhanced performance observed with ZIF-8 and MIZIFs treated crops. This is consistent with research in other crops showing the yield promoting impacts of nano-scale metal and micronutrient treatments.

Most important, the plants treated with MiZIFs showed an almost two-fold increase in fruit zinc content, which is very promising for micronutrient fortification, indicating a positive impact of encapsulated MiZax on the enhancement or transportation of zinc from the rhizosphere to the fruit.

Alagoz says the work opens up possibilities of employing other biocompatible and economically viable coordination-based systems for specific micronutrient delivery in precision agriculture.

"This is the first study to show the successful packaging of MiZax-3 with

MiZIFs as a smart agrochemical delivery platform to improve crop yield and fruit zinc content in capsicum on a field scale," he notes.

The team is now running even larger scale experiments at different locations and in varied seasons to collect more data for using this smart platform on other crop species. Their research was also selected to be highlighted on the *Science* website as a research highlight from other journals.

More information: Katya M. Aguliar Perez et al, Biomimetic Mineralization for Smart Biostimulant Delivery and Crop Micronutrients Fortification, *Nano Letters* (2023). DOI: 10.1021/acs.nanolett.2c04506

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