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Nanotechnology, is it something useful for future agriculture?

Nanotechnology has been applied in various fields – biomedicine, electronic devices, renewable energy optical electronic medicine, physics, pharmaceutics. Does it have a place in agriculture?

It is generally accepted that manipulation of a crop's native microbiome represents a promising strategy for addressing many of the challenges posed by the stress of climate change to soil health as well as to agricultural productivity. Naturally existing beneficial microorganisms that colonise plant roots are known to mediate enhanced resistance to biotic stressors, as well as increase abiotic stress tolerance. Thus microbiome engineering in situ using molecular and biochemical methods could provide effective sustainable outcomes. Yet it is clear that several questions need to be answered before large scale field application. The major challenge is reproducibility under natural conditions. The microbial inoculants have to be prepared and formulated so that a stable microenvironment is formed for a sustained period of time enabling beneficial microbes to exert their beneficial effect, e.g. by creating bacterial layers on the root surface. The microenvironment should also provide physical protection for the microorganisms and ensure the favourable conditions for the effect. This microenvironment could be, for instance, a plant root biofilm. We used titania nanoparticles (TN) to create the synthetic biofilms (Fig. 1).

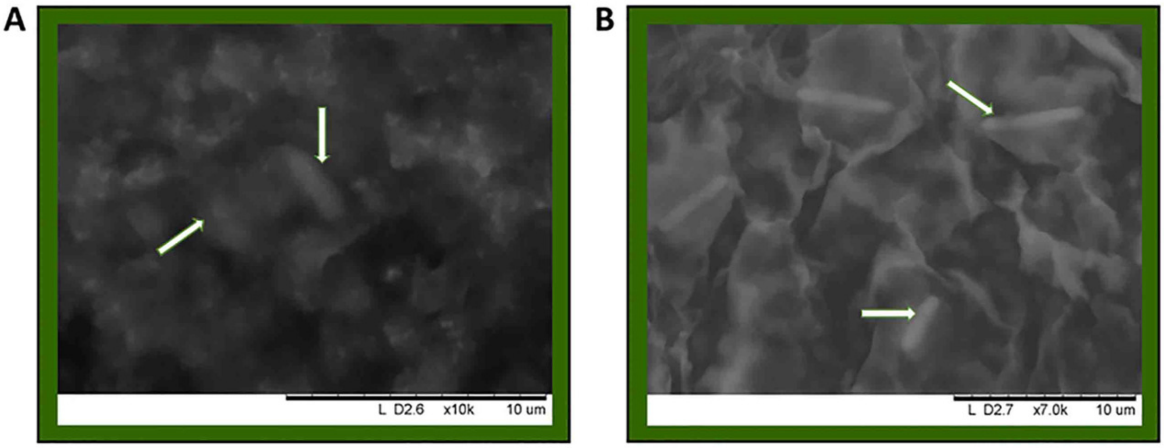

Fig. 1. Titania nanoparticles reinforce Bacillus thuringiensis AZP2 biofilm.
Scanning electron microscopy micrographs of Bacillus thuringiensis AZP2 cells (A) and cells grown with titania nanoparticles (TN's) (B).

We monitored the colonization by the bacteria and their combinations and the effect on the biomass of wheat seedlings during two weeks of stress induced by the pathogen *Fusarium culmorum*, drought and salt. The plant-beneficial bacteria were applied as single or double inoculants with and without titania nanoparticles. The TN-supported microenvironment did not significantly improve the microbial performance in the case of single inoculation. Fascinatingly major differences in seedling biomass were observed when double inoculations with TNs were performed. The two inoculant combinations resulted in enhanced colonisation and about 25% increased seedling biomass owing to the improved colonisation (Fig. 2). Regression analysis indicated that there is a positive interaction between the second inoculant and seedling biomass, and that plant biomass increases with increase of colonisation by the second inoculant.

The TNs used by us were prepared by Sol Gel technology. Engineered nanoparticles are formed mainly by reduction of metal ions followed by functionalization of the NPs' surface. Beside engineered NPs such as metals, non-metals, metal oxides and lipids, polymer NPs are formed naturally. Natural NPs cover the atmosphere, hydrosphere, lithosphere and even biosphere. They are formed by chemical, mechanical, thermal and biological processes, weathering, and mechanical processes combined with precipitation and colloid formation. Our results show that nanoparticles, both synthetic (TNs) and natural silica nanoparticles, have roles in the rhizosphere bacterial interactions with plants and may hold the key to the reproducible application of plant beneficial microorganisms in food security programs. NPs have unique physical and chemical properties and due to their small size are characterized by huge surface area. The NPs effect is mediated by the particles ability to modulate the surface formation of complexes with important type of biomolecules. Therefore we are in the process of studying the pathways that aim to improve the effectiveness of NPs and optimise their mutually complex interactions with crop plants. This has to be performed on the background of plant genotype and environment interactions.

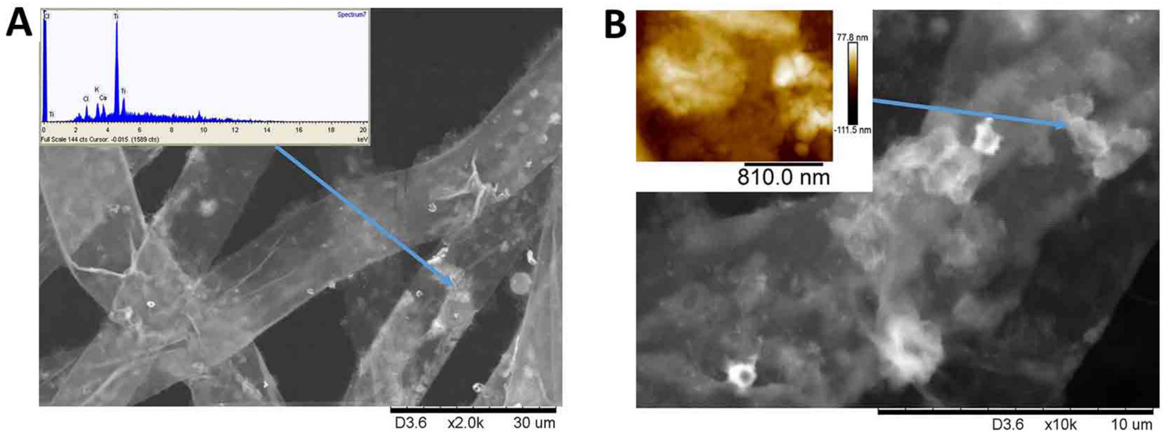

Fig. 2. Bacterial –nanoparticle (NP) aggregates on plant root.
Typical scanning electron microscopy – energy-dispersive X-ray spectroscopy images of bacterial cells grown with NPs for 24 hours on plant root after 6 hours of inoculation (A). atomic force microscopy image with the characteristic aggregate sizes of 50–60 nm (B).

In summary, the main challenge for microbiome application is ensuring the microbiome stable colonisation. Our results revel that nanoparticles can contribute improving the colonization and encourage nanotechnology application in agriculture.

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Publication

Titania (TiO2) nanoparticles enhance the performance of growth-promoting rhizobacteria.
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