European Commission

Science for Environment Policy

Silver nanoparticles can have complex and toxic effects on wheat roots

A new study has examined the toxic effects of silver nanoparticles on plants. Using a range of spectroscopic and imaging techniques, the researchers demonstrate how silver nanoparticles can reduce the growth of wheat, as well as interfere with genes that help the plant deal with pathogens and stress.

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Engineered nanoparticles can accumulate within agricultural soils due to their presence within sewage sludge, which is spread on agricultural land. Current regulations concerning sewage sludge focus on the content of certain metals, but do not consider nanomaterials. Silver nanomaterials are also widely used in products such as pesticides, due to their biocidal properties, which can then also make their way into soils. Plants have not evolved to cope with silver toxicity, as silver is not naturally found in high concentrations in soils. Silver nanoparticles are likely toxic to plants because of the release of silver ions and the properties related to their small size.

Sulfidation is the transformation of silver nanoparticles into silver sulfide. Silver nanoparticles are found in fabrics and other consumer products. Sulfidation can occur, for example, when washing clothes; the nanoparticles in fabrics can be partly sulfidised during laundry and then complete their sulfidation during wastewater treatment. As silver sulfide is not water soluble, sulfidation is considered as a potential way of reducing the toxicity of silver nanomaterials. Thus may not be the case, however, with nano silver sulfide. This study aimed to understand how metallic silver nanoparticles and silver sulfide nanoparticles are transformed, taken up and transported when in contact with wheat plants, and the toxic impacts of these nanoparticles.

Laboratory-grown wheat plants (*Triticum aestivum* L.) were randomly selected and three groups of 12 plants were transferred to glass pots containing 2 litres of one of four solutions: a nanoparticle suspension solution containing pristine metallic silver (AgNP) and sulfidised silver (Ag_2SNP); a solution containing ionic silver ($AgNO_3$); and a control group with no silver addition. The system was continuously aerated and agitated in order to keep the nanoparticles in suspension.

After three weeks, the researchers used various spectroscopic and imaging techniques to assess the movement and distribution of nanoparticles within the wheat roots and shoots and the chemical changes to nanomaterials and $AgNO_3$, to understand the potential toxic impacts on the plants. Techniques used included plasma mass spectrometry and various x-ray spectroscopic and imaging techniques, including 3D imaging. The gene expression — how genes are activated to produce proteins — of selected genes was also analysed to assess any effects of the silver nanomaterials.

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The imaging techniques showed how nanoparticles accumulated within the wheat roots, which may have an impact on root function. For example, metallic nanoparticles caused a reduction in secondary root (a side branch of the main or primary root) growth and an increase in the growth of root hairs, which is often related to a lack of water or nutrients. The accumulation of silver in plant tissue was also associated with a reduction in the growth rate of plants, with the largest growth reduction occurring in wheat plants treated with the metallic nanoparticles and ionic silver. Analysis of the plants' gene expression also showed an impact on genes that control the defence against pathogens and mechanisms that cope with stress.

The researchers say the study demonstrates the complicated impacts that nanomaterials can have on plants and the importance of assessing different factors to understand the toxic impacts on plants. Specifically, the researchers point to the need to understand the type of nanoparticle that the plant is exposed to and the forms that are to be found in the exposure media and within the plant, which can have a major bearing on the toxic effects.

The researchers say that, though their study uses low doses related to previous studies, they are now focusing their efforts on the study of silver nanoparticles in soil systems to create environmental conditions as close as possible to real-world conditions. Only three previous studies have examined the transfer of silver sulfide nanoparticles within plants.

The researchers say that silver sulfide nanoparticles are not as stable as expected when exposed to plant roots and are phytotoxic, showing that that the sulfidation of silver nanparticles is not a perfect antidote to toxicity. In agricultural soils, silver sulfide could partly dissolve, leading to negative impacts on crops and the environment.