EARTH SCIENCES
Published: 27 November 2024
doi: 10.3389/frym.2024.1355364

DO NANOPARTICLES AFFECT CROP GROWTH AND SOIL BACTERIA?

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YOUNG REVIEWERS:

OFUNWA
AGE: 9

VUSANI
AGE: 10

Did you know scientists can make tiny structures called nanoparticles, which are smaller than the smallest ants? Nanoparticles are useful for a lot of different things, including helping farmers grow our food crops. Without fertilizers, which are nutrients applied to gardens and farms to help crops grow, it would be difficult to grow enough vegetables and fruits to support all the humans on Earth. However, some fertilizers are too big to be easily taken up by plants. Because nanoparticles are so tiny, they can easily get into plants and help them grow. But there is a downside—sometimes nanoparticle fertilizers disturb the growth of natural organisms in the soil, such as bacteria. Some soil bacteria also help plants to grow, so they need to be protected. It is therefore important to understand how nanoparticle fertilizers affect the bacteria in the soil.

WHY DO WE NEED FERTILIZERS?

By 2050, there will be more than 9.7 billion people on the planet [1]. To feed all these people, farmers will need to produce more food than they do today. To ensure that no one goes hungry, we need to come up with farming techniques that both produce lots of food *and* are safe to the environment. Farmers generally use **fertilizers** to help their crops grow. Fertilizers provide important nutrients that plants need to thrive. The problem is that the common chemical fertilizers that farmers use consist of large particles, which generally do not enter plants very easily because of their size. As a result, during heavy rains and floods, these fertilizers are washed out of fields and into waterways, like rivers and groundwater. This can be bad for the environment and unhealthy for humans [2]. Good farming methods require fertilizers that are fully used by the plant, with less washout during rains.

FERTILIZER

A natural or factory-made product containing chemical elements such as nitrogen, phosphorus and potassium, which act as food for plants and help them grow.

Nanoparticles are very tiny particles that are measured in nanometres. A million nanometres is equal to a single millimeter (mm), so nanoparticles are much smaller than the smallest known ant, which is about 1 mm long (Figure 1). Nanoparticles have been used in several kinds of industries [3]. For example, nanoparticles can be found in medical test equipment and cleaning solutions like detergents, because they can fight germs. Nanoparticles are also used in agriculture as nanopesticides to protect crops and as nanofertilizers to help them grow. Because of their tiny size, nanoparticles can enter crop plants more easily than traditional fertilizers can, so they can be used to efficiently deliver nutrients that boost plant growth [3]. When used in this way, they are called **nanofertilizers**. If they are taken up by plants more easily, nanofertilizers might have less washout, which means these fertilizers could be less harmful for the environment.

NANOPARTICLES

Tiny structures that have a size range between 1 and 100 nanometres. One nanometre is 1/1,000,000 of a millimeter.

NANOFERTILIZER

A fertilizer formulated with nanoparticles to help the plant grow

Figure 1

Figure 1

Nanoparticles are measured in nanometres (nm), with one nanometre being one millionth of a millimeter (mm). The smallest known ant is 1 mm in length.

However, not all nanoparticles can act as fertilizers as some nanoparticles can be too dangerous for the plant. In most cases, the nanoparticles that are mostly helpful in plants are those that are known nutrients such as zinc, iron and others. Some nanoparticles such as silver and titanium are used to clean contaminated water and can also be incorporated in membranes or filters to allow the water to pass through for purification.

The use of nanoparticles as nanofertilizers is very helpful however, there is another factor farmers must consider in their choice of fertilizers—microorganisms that live in the soil, such as **bacteria**. Soil contains bacteria that are both good and bad for crops. Bad bacteria can delay or stop plant growth, while good bacteria can help plants grow by making nutrients available to them. When nanofertilizers are used, they might affect the growth of bacteria in the soil [4]. We did not know whether nanoparticles would inhibit or improve the growth of soil bacteria, so we decided to do an experiment to test this.

BACTERIA

Living organisms that are found everywhere on the planet but cannot be seen with the naked eye, only through a microscope.

HOW DO NANOPARTICLES AFFECT SOIL BACTERIA?

First, we studied the effect of nanoparticles made of a substance called iron oxide on a type of bacteria called *Bacillus subtilis*. *Bacillus subtilis* can be grown in the laboratory, so it is easy to do experiments on, but this type of bacteria was also chosen because it is found in soil, where it is good for plant growth. The experiment was done by growing *Bacillus subtilis* on a culture plate containing nanoparticles along with the nutrients that the bacteria need to grow.

To clearly show whether nanoparticles negatively affect bacteria, we needed to include a **control** in our experiment—something that was *known* to have an effect on bacteria, so that we would have something to compare the effect of nanoparticles to. Antibiotics are medicines doctors use to kill bacteria, so we placed small discs of paper soaked in antibiotics on our control culture plate. In Figure 2A, you can see the clear zones around the antibiotic discs where the bacteria cannot grow. No clear zones (cloudy surface) around the discs mean bacteria can still grow, and this is what we saw in the presence of our iron oxide nanoparticles (Figure 2B), meaning that these nanoparticles did not hinder the growth of *Bacillus subtilis*.

CONTROL

Part of an experiment that shows the expected result, proving the experiment setup works. It helps scientists compare and confirm their results.

HOW DO NANOPARTICLES AFFECT SEEDS?

We also wanted to test whether seeds could still **germinate** in the presence of the iron oxide nanoparticles. This was done to prove whether the nanoparticles can also act as a fertilizer. To test this, we placed carrot seeds on damp filter paper in culture dishes, either with or without nanoparticles. As our control, we did the experiment with water alone and with no addition of the nanoparticles, as shown in Figure 3A. We found that the nanoparticles in Figure 3B were able to improve germination of carrot seeds compared to the control test without nanoparticles in Figure 3A. The length of the overall plant when nanoparticles were used increased to 82 mm, while the length of the plant when water with no nanoparticles was used increased

GERMINATION

The development of a seed to form a plant, also called sprouting.

Figure 2

(A) As a control for our experiment, we used small discs soaked in antibiotics, which kill/prevent the growth of bacteria. You can see the clear circle around the discs where bacteria cannot grow. **(B)** To test whether nanoparticles affected the growth of bacteria, we used tiny discs soaked in nanoparticles instead of antibiotics. No clear circle around the discs prove that the nanoparticles did not stop the bacteria from growing. This tells us that nanoparticle fertilizers might be able to help plants grow without harming helpful soil bacteria.

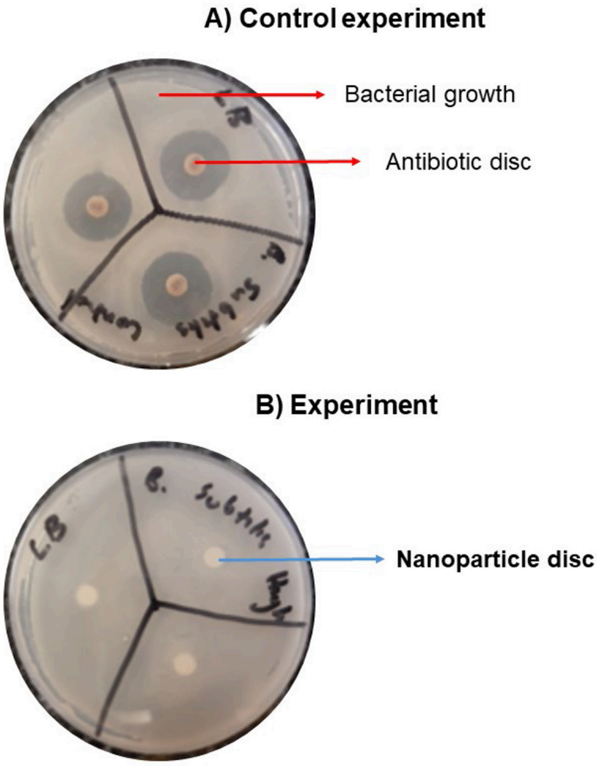

Figure 2

to 27 mm. Both seeds in Figures 3A, B were germinated for 12 days. This means that even though plants can still grow using water alone for germination, adding nanoparticles for seed germination of carrot can increase the growth of the plant 3 times in comparison to using water alone.

Figure 3

(A) Germination of carrot seeds on filter paper soaked in water without nanoparticles, **(B)** Germination of carrot seeds on filter paper soaked in water containing nanoparticles. Germination was done for 12 days. The seeds grown in nanoparticle solution grew much taller than the ones grown in just water, this shows that nanoparticles can improve seed germination thereby helping plants grow.

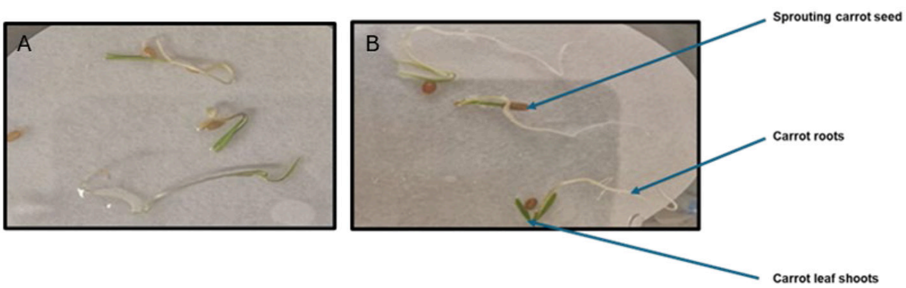

Figure 3

WHAT CAN WE LEARN FROM THESE RESULTS?

To feed the increasing number of people in the world, it is important to test new ways of promoting crop growth that are safe for the environment. We tested nanoparticles to understand whether they can help carrot seeds germinate and grow faster. We also looked at the effect of nanoparticles on a helpful type of soil bacteria, *Bacillus subtilis*. This was done because we need to know if nanoparticles are used as fertilizers, will they affect the growth of helpful microorganisms in soil. We discovered that small amounts of nanoparticles can help carrot seeds to germinate faster, and that the nanoparticles did not harm the bacteria. These results show that it might be safe to use low amounts of nanoparticles as nanofertilizers to promote plant growth.

ACKNOWLEDGMENTS

We acknowledge L'Oréal-UNESCO FWIS Programme and National Research Foundation (NRF); Grant numbers (121924 and 129651). The Agricultural Research Council (ARC) is also acknowledged for the support provided to undertake this research. Opinions expressed and conclusions reached are those of the authors and not necessarily endorsed by L'Oréal-UNESCO, NRF and ARC.

ORIGINAL SOURCE ARTICLE

Ndaba, B., Roopnarain, A., Vatsha, B., Marx, S. and Maaza, M. 2022. Synthesis, characterization, and evaluation of artemisia afra-mediated iron nanoparticles as a potential nano-priming agent for seed germination. *ACS Agric. Sci. Technol.* 2:1218–29. doi: 10.1021/acsagscitech.2c00205

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SUBMITTED: 08 January 2024; **ACCEPTED:** 06 November 2024;
PUBLISHED ONLINE: 27 November 2024.

EDITOR: Tarryn Lee Botha, University of Johannesburg, South Africa

SCIENCE MENTORS: Refilwe Lukhwareni and Nonhlangabezo Mabuba

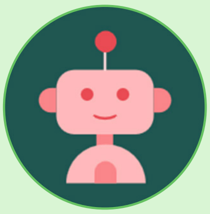
CITATION: Ndaba B, Rama H and Roopnarain A (2024) Do Nanoparticles Affect Crop Growth and Soil Bacteria? Front. Young Minds 12:1355364. doi: 10.3389/frym.2024.1355364

CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

OFUNWA, AGE: 9

He is a bright and bubbly 9-year-old with an infectious enthusiasm for life. Talkative and sweet, he can chat endlessly about his favorite video games, sharing tips and tricks with anyone who will listen. His intelligence shines through in his love for reading, Whether he is immersed in a game or exploring a new book, his curiosity and kindness make him a joy to be around. He always tries to find interesting facts about different planets and the entire solar system.



VUSANI, AGE: 10

Vusani is 10 years old and is attending Weltevreden Park Primary School. He is in grade 5 and loves to do Maths. He reads about theories to test if they are facts. He creates his own fantasy world by telling new stories to his friend and drawing characters. On Saturdays, he visits the library to read about the new comic books. He likes to play football and TV games with his brother and sister.

AUTHORS

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Busiswa Ndaba is a senior lecturer at the University of South Africa, College of Science, Engineering and Technology, South Africa. Her research focuses on producing nanoparticles in the laboratory for their use in the production of renewable energy (biogas, bioethanol, biobutanol) as well as in agriculture as fertilizers for a circular economy. Her interests are in developing sustainable methods for the energy and agricultural sectors. Busiswa likes hiking, reading, watching movies, and having a good time with family. *ndabab@unisa.ac.za

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Haripriya Rama is a researcher at the Agricultural Research Council-Natural Resources and Engineering, South Africa. Her research study focuses on the effect of two nanoparticles produced via greener methods on biogas production and digester microbial communities. Her research interests are in developing sustainable solutions to clean the environment via anaerobic digestion and exploring the potential capabilities of microorganisms. Haripriya enjoys reading, hiking, and spending time with family and friends.

ASHIRA ROOPNARAIN

Ashira Roopnarain is a microbiologist whose research focuses on renewable energy generation from organic wastes. She is particularly interested in how to improve biogas production in low-cost anaerobic digesters using cost effective and environmentally friendly methods. Ashira is a senior researcher at the Agricultural Research Council of South Africa. Outside work, Ashira enjoys spending time with her family, reading, gardening, and traveling.