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The Hidden Helpers inside Ginger: Endophytic Bacteria as Natural Defenders against *Pythium* Soft Rot

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Soft rot in ginger is one of the most serious problems affecting ginger cultivation. It is caused by *Pythium*, a fungus-like water mould. The disease spreads rapidly in warm and wet conditions and can greatly reduce harvests or even destroy entire fields. These organisms can survive in soil for years through tough survival structures called oospores. When favourable conditions return, these hidden structures become active again and restart the infection cycle. They cause severe damage to seeds and young seedlings by infecting roots and stem tissues, leading to damping-off disease before and after seed emergence. Since *Pythium* can infect many different plants and persist in the environment for long periods, managing soft rot remains a major challenge for farmers.

Farmers employ various management practices for soft rot control, including

- Growing resistant ginger varieties
- Cleaning and treating seed rhizomes before planting to reduce disease spread
- Practising crop rotation to lower pathogen buildup in soil
- Using soil solarization by covering moist soil with clear plastic during hot months to kill harmful microbes and pests
- Adding organic soil amendments such as neem cake and oilseed cake to improve soil health
- Applying beneficial microbes like *Trichoderma*, *Pseudomonas*, plant growth-promoting bacteria, and *Bacillus amyloliquefaciens* to naturally protect plants and promote healthy growth.
- Chemical fungicides such as Mancozeb, Metalaxyl, copper oxychloride, carbendazim, ziram, propineb, fludioxonil, and metalaxyl-mancozeb are also used as seed rhizome treatments and soil applications to control soft rot disease.

When *Pythium* soft rot spreads in ginger fields, farmers often use chemical fungicides to protect their crops. While these chemicals can help control the disease, excessive use may harm soil health and the environment. Studies found that combining different methods works better for controlling soft rot naturally and sustainably.

A natural way to protect ginger crops

Plants naturally contain helpful bacteria called endophytes that live inside their tissues. These tiny microbes support plant growth, protect plants from harmful pathogens, and produce natural compounds that slow disease spread. They can also strengthen the plant's own defence system, helping it resist infections more effectively. Plants from the ginger family are rich in medicinal compounds, essential oils, and phytochemicals, making them a natural home for many beneficial endophytic microbes. Researchers are now exploring these hidden microbes for their potential to control soft rot disease in ginger. Some endophytic bacteria produce antibiotic-like and volatile substances that can inhibit harmful pathogens such as

Pythium, while others enhance the plant's natural defence system, helping ginger plants resist infection more effectively.

Fighting plant disease with natural compounds from beneficial bacteria

Scientists are now exploring beneficial bacteria that naturally live inside ginger plants. These microbes may offer a safer, more eco-friendly alternative to excessive chemical use. Instead of relying solely on fungicides, farmers could use these natural microbes to sustainably protect crops. Researchers found that these beneficial bacteria can weaken the soft rot pathogen by damaging its outer structure by producing volatile organic compounds. Under microscopic observation, the harmful fungus-like organism showed shrinkage, breakage, and damage to its surface, making it weaker and less able to spread disease (Figure 1).

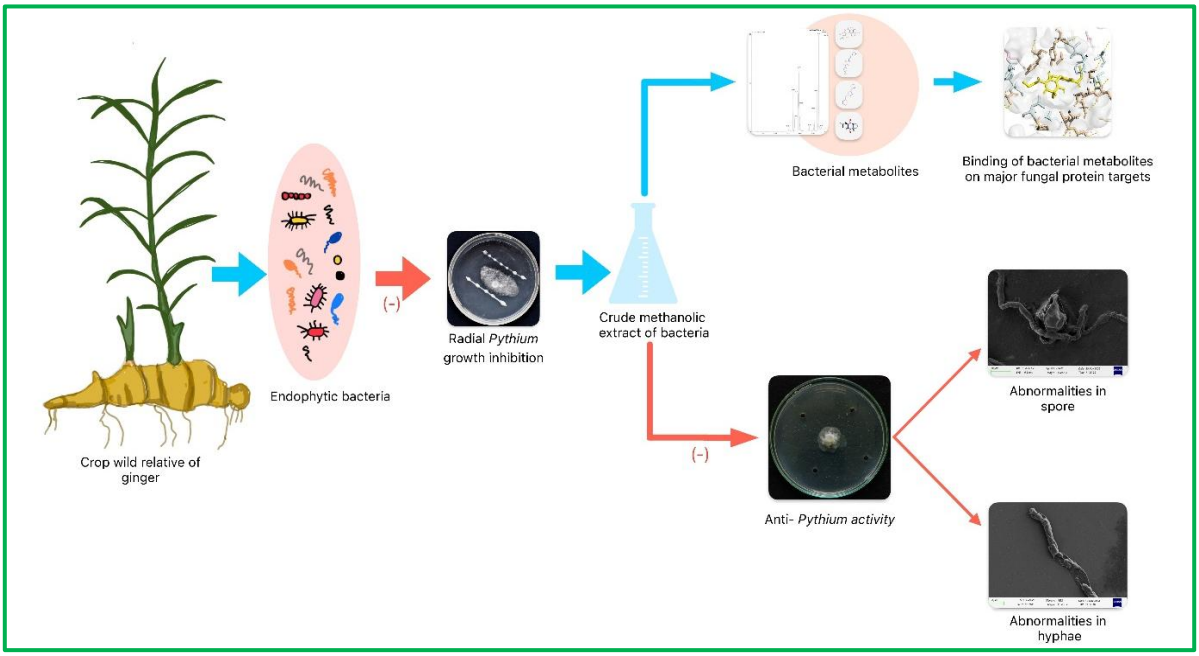

Figure 1. Beneficial bacteria living inside ginger plants produce volatile organic compounds that protect ginger from *Pythium* soft rot by damaging the pathogen's mycelia and spores and targeting key proteins involved in its growth.

Although these beneficial endophytic bacteria can naturally fight *Pythium* and other plant pathogens, their performance in real farm conditions is not always consistent. Changes in temperature, soil conditions, and environmental stress can reduce their effectiveness. Many beneficial microbes also struggle to survive for long periods in the field. Because of this, scientists are working on developing better formulations that help these helpful bacteria stay alive, active, and effective for longer, making biological disease control more reliable for farmers.

Biopesticides made from beneficial microbes are available in different forms such as talc-based powders, lignite-based powders, wettable powders, bentonite and polyethene glycol (PEG) pastes, water-dispersible tablets, liquids, and granules. Helpful microbes like *Bacillus subtilis*, *Pseudomonas putida*, and *Trichoderma* are widely used to protect plants from diseases. These natural products can be applied by spraying, dipping, drenching or seed treatments, which reduces infections and keeps them healthier for longer.

Key points for successful microbial application

Biocontrol microbes often show excellent results in the laboratory, but their field performance can be inconsistent. Therefore, proper selection and application are essential for successful disease management. A successful application depends on

1. **Proper storage**

- Store in a cool, dry place away from direct sunlight.
- Avoid exposure to high temperatures.

2. **Apply at the right time**
- Prefer application during cooler hours (morning or evening).
- Ensure adequate soil moisture for microbial establishment.
3. **Avoid incompatible chemicals**
- Do not mix bioinoculants directly with fungicides, bactericides, or strong chemical pesticides.
- Maintain an interval of 5–7 days between chemical and microbial applications.
4. **Use suitable organic matter**
- Addition of compost, farmyard manure, vermicompost, or neem cake improves microbial survival and activity.
5. **Maintain favourable soil conditions**
- Moderate soil pH (generally 6.0–7.5) is ideal for most beneficial microbes.
- Avoid waterlogging and excessive soil dryness.
6. **Correct application method**
- Follow recommended doses for seed treatment, root dipping, soil application, or drenching.
- Ensure uniform distribution in the root zone.
7. **Apply near the root zone**
- Beneficial microbes must colonize roots for maximum effectiveness.
8. **Use fresh inoculum**
- Do not use expired or improperly stored products, as microbial viability declines over time.

Although more research is still needed, endophytic bacteria from the ginger family are showing great promise as nature's tiny defenders against soft rot disease. They protect ginger plants by fighting harmful pathogens and strengthening the plant's natural defences. In the future, these hidden microbes could help farmers grow healthier ginger crops while protecting soil health and the environment.