



Before the Disease Arrives: How Microbes Prime Tomato Plants for Defense

*Shreya. S¹, Ashwini. M², Sandeep. J¹ and Kushan. A³

¹M.Sc. I Year, Department of Microbiology, College of Agriculture, Dharwad, University of Agricultural Sciences, Dharwad, Karnataka

²Associate Professor, Department of Microbiology, College of Agriculture, Dharwad, University of Agricultural Sciences, Dharwad, Karnataka

³M.Sc. II Year, Department of Microbiology, College of Agriculture, Dharwad, University of Agricultural Sciences, Dharwad, Karnataka

*Corresponding Author's email: shreyakotagi29@gmail.com

Plants cannot run away from disease. Instead, they have evolved sophisticated defence systems that can recognize danger and respond to it. Interestingly, certain beneficial microorganisms can prepare plants for future attacks without continuously activating costly defence responses. This phenomenon is known as induced systemic resistance (ISR). Beneficial microbes associated with plant roots can prime the plant so that, when a pathogen arrives, defence responses are activated more rapidly and strongly. Tomato is an important model for studying this phenomenon. Research has shown that beneficial microorganisms can influence hormone signalling, reactive oxygen species, defence enzymes and other components of plant immunity.

Keywords: Tomato, induced systemic resistance, microbial priming, plant immunity, beneficial microorganisms, plant defence, rhizobacteria

Introduction

Imagine a tomato plant growing quietly in a field.

Nothing appears to be happening.

Then a pathogen arrives.

Within a short time, the plant begins activating its defence machinery.

But what if the plant had already received a warning?

This is where beneficial microorganisms become fascinating.

Certain bacteria and fungi living around plant roots can interact with the plant and place it in a “primed” defensive state. The plant is not necessarily fighting continuously. Instead, it becomes better prepared to respond when an actual threat appears.

It is almost like microbial training for plants.

What Is Microbial Priming?

Priming means that a previous biological experience prepares the plant to respond more effectively to a later challenge.

In microbial-induced systemic resistance, beneficial microorganisms can establish interactions around the roots and trigger changes in the plant's defence system.

The plant may remain apparently normal.

But when a pathogen attacks, the response can be faster or stronger.

This is one of the most interesting concepts in plant-microbe biology because the microorganism is not simply killing the pathogen.

It is helping the plant defend itself.

The Microbe Sends the First Signal

Beneficial microorganisms can produce a variety of molecules that plants can perceive. These include microbial metabolites, volatile compounds, siderophores and other molecular signals.

The plant recognizes these signals through its own sensing systems and begins adjusting its internal signalling pathways.

The remarkable part is that the signal can originate near the roots while the eventual defence response may appear in leaves and other distant tissues.

The message travels.

The whole plant gets ready.

The Root Sends a Warning Upstairs

The root is not merely an organ for absorbing water and nutrients.

It is also an important communication centre.

When beneficial microorganisms interact with roots, the plant can initiate signalling pathways that influence tissues far away from the original microbial contact.

This systemic communication is central to induced systemic resistance.

A microbe at the root can therefore influence how a leaf responds to a pathogen.

In simple terms:

Root interaction → signal → whole-plant preparation → faster defence

The Hormone Switchboard

Plant defence is controlled by interconnected signalling pathways.

Among the most important are jasmonic acid, ethylene and salicylic acid.

Different beneficial microorganisms can influence these pathways in different ways, and ISR is often associated with jasmonic acid and ethylene signalling, although the relationship is more complex than a single pathway.

Rather than functioning like separate switches, these hormones behave more like a communication network.

One signal can influence another.

The plant constantly adjusts the balance according to the type of threat it encounters.

The Plant Does Not Waste Energy

Constantly keeping every defence mechanism switched on would be expensive for a plant.

Growth, reproduction and defence all require energy.

Priming offers an interesting compromise.

The plant can remain in a relatively prepared state without maintaining maximum defence activity all the time. When a pathogen appears, the defence response can be activated more rapidly.

It is similar to keeping emergency equipment ready rather than using it every minute.

When the Pathogen Finally Arrives

Now imagine a pathogen reaching a primed tomato plant.

The plant recognizes danger.

Defence signalling accelerates.

Reactive oxygen species can be produced.

Defence-related enzymes become active.

Cell-wall strengthening and other protective responses can occur.

The plant essentially moves from “prepared” to “responding.”

This faster response can make it more difficult for some pathogens to establish and spread.

The Invisible Chemical Alarm

One of the earliest responses to microbial recognition can involve reactive oxygen species.

Although excessive reactive oxygen species can damage cells, plants also use them as signalling molecules.

They can act like chemical alarms that help coordinate defence responses. Beneficial microorganisms can influence this system, helping plants regulate their oxidative responses when challenged by pathogens. So molecules often associated with cellular damage can also become part of the plant's emergency communication system.

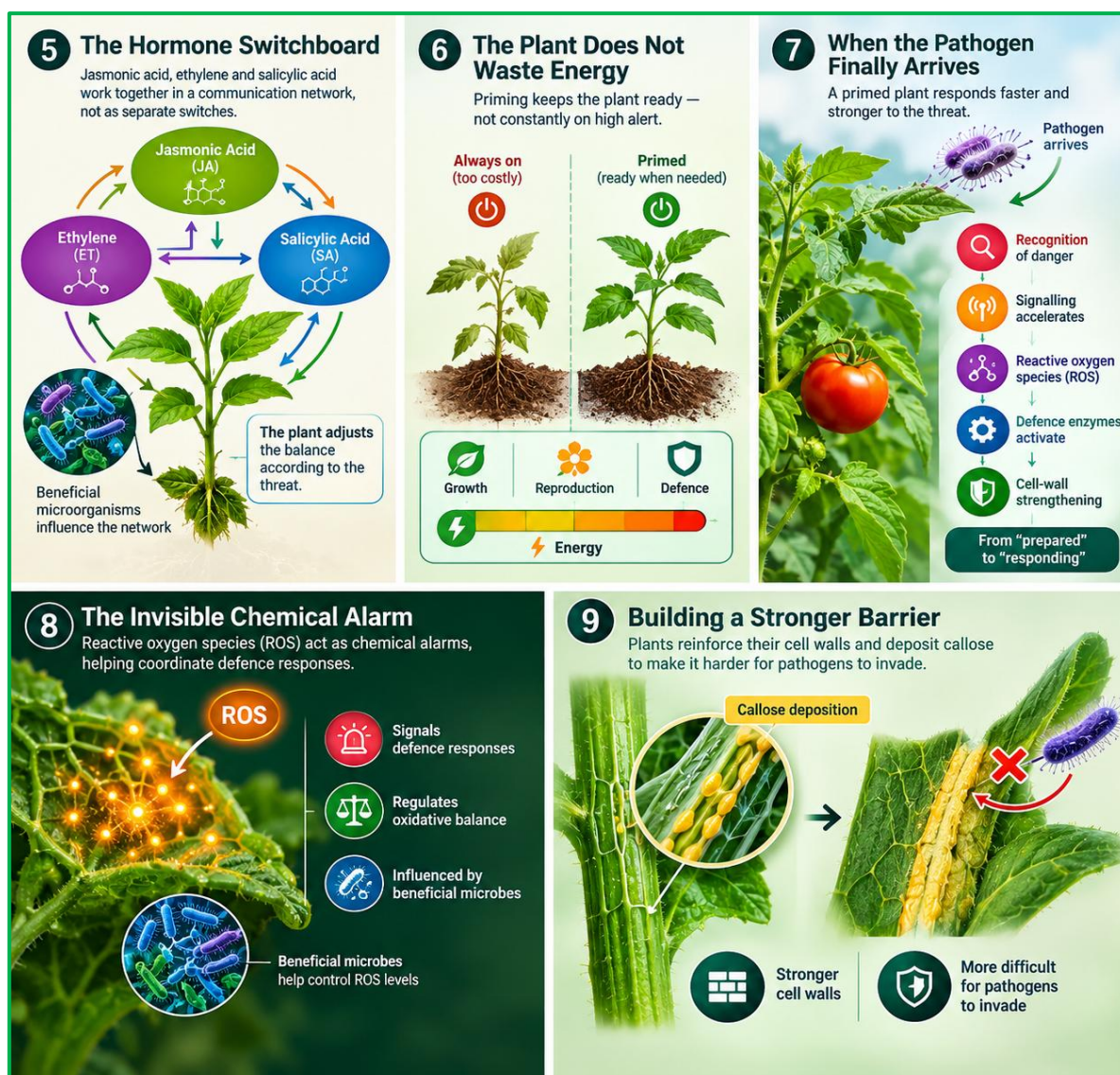


Figure 1: The Plant Defense Switchboard: From Priming to Protection

Building a Stronger Barrier

Plants also possess physical barriers against invading pathogens. Cell-wall reinforcement is one important component of defence. During induced resistance, processes such as callose deposition can contribute to strengthening plant tissues around potential infection sites. The result is not simply chemical warfare. The plant can make itself physically more difficult to invade.

Tomato: A Fascinating Example

Tomato has become an important model for studying induced resistance because it interacts with a wide range of microbial pathogens. Beneficial microorganisms including *Bacillus*, *Pseudomonas*, *Trichoderma* and mycorrhizal fungi have been investigated for their ability to influence tomato defence. A systematic review found tomato to be the most extensively studied plant species among the literature it examined on microbial-induced systemic resistance. This makes tomato a useful window into the larger world of plant immunity.

Lactic Acid Bacteria Join the Story

This becomes particularly interesting when we return to lactic acid bacteria.

LAB are usually associated with fermentation and food microbiology, but they have also been investigated for plant growth promotion and disease suppression.

Research in tomato has shown that LAB can influence defence-related enzymes and biochemical responses against bacterial wilt caused by *Ralstonia solanacearum*.

More recently, a 2026 study reported that cell-free culture filtrates from LAB promoted tomato seedling growth and reduced disease severity caused by *R. solanacearum*, while influencing antioxidant and salicylic-acid-associated defence responses.

This suggests that the bacteria may not always need to physically remain on the plant to influence its biology.

Their molecules can matter too.

The Microbe Does Not Have to Be the Warrior

This is perhaps the most important idea in the entire story.

A beneficial microorganism does not necessarily need to directly destroy a pathogen.

It can instead influence the plant's own defence machinery.

The pathogen arrives.

The plant recognizes it.

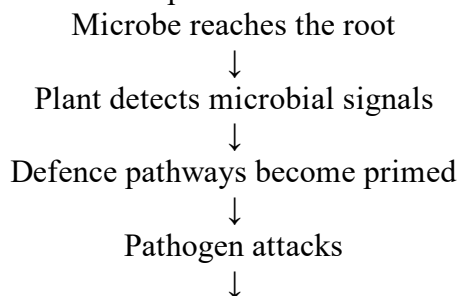
The previously prepared defence system responds.

In this way, the plant itself becomes the primary defender.

The microorganism may simply be the trainer.

A Simple Defence Story

The process can be understood in five steps:



Tomato responds faster and more strongly

This simplified pathway captures the central idea of microbial-induced systemic resistance without reducing the underlying biology to a single mechanism.

What We Still Do Not Know

The more scientists discover about microbial priming, the more questions appear.

Which microbial signals are most important?

How does a tomato plant distinguish beneficial microbes from pathogens?

How long does the primed state last?

Can different beneficial microorganisms work together?

Why does the same microbial strain produce different responses under different environmental conditions?

These questions are driving current research into plant immunity and microbiome engineering.

The Future of Microbial Priming

The future may involve more than simply applying one beneficial microorganism to a crop.

Researchers are increasingly interested in selecting microbial strains according to their specific functions and understanding how microbial communities influence plant immunity.

The long-term goal could be to develop microbial treatments that prepare crops for particular stresses while minimizing unnecessary energy costs to the plant.

In other words, agriculture may eventually learn not only how to protect plants, but how to help plants prepare themselves.

Conclusion

Plants have their own defence systems, but they do not always operate alone.

Beneficial microorganisms can communicate with plants and influence their internal signalling networks. Through induced systemic resistance, selected microbes can prime plants for stronger responses when pathogens eventually arrive.

In tomato, research has connected beneficial microorganisms with changes in defence enzymes, hormones, reactive oxygen species and other protective mechanisms. LAB have also emerged as an interesting example, with recent studies showing their potential to influence tomato growth and resistance to bacterial wilt.

The most fascinating part is that the microbe does not always need to fight the enemy.

It may simply whisper a warning to the plant.

And when the real attack comes, the plant is already listening.

Sometimes, the best defence is not fighting earlier. It is being prepared earlier.

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