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EARTH SCIENCES
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HELPING PLANTS FIGHT BACK AGAINST PESTS AND DISEASES

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YOUNG REVIEWERS:

ARIANNA
AGE: 11

JAMARION
AGE: 10

NOAH
AGE: 10

ZURI
AGE: 10

Feeding the world's growing population is a huge task, made even more challenging by pests and diseases that threaten crops. For years, pesticides and other chemical treatments have been the common solution, but these chemicals can be dangerous for the environment, and they have been used so much that many of them no longer work well. The world needs a better solution. Fortunately, plants have natural defenses against pests and diseases. Through a process called induced resistance (IR), plants can "ramp up" these defenses, making them stronger in the face of multiple threats. Researchers are exploring ways to activate IR in healthy plants to protect them against future dangers. This fascinating strategy could help to reduce pesticide use—a win-win situation for both farmers and the environment! In this article, we will explain the natural defenses of plants, describe why IR might be a great way to protect

crops, and discuss the scientific challenges still to be faced on the path to sustainable farming.

THE IRISH POTATO FAMINE: A LESSON IN CROP PROTECTION

For many of us, fruits, vegetables, and grains are easy to get at local markets or grocery stores, and we might be so used to produce being readily available that we take these crop plants for granted. However, this abundance is not reality for everyone. In some parts of the world, maintaining a steady supply of food is a challenge, sometimes due to the threat of pests and diseases that can wipe out vital crops. According to the United Nations, 20%–40% of crops worldwide are lost to pests each year. This is super expensive—plant diseases cost the global economy around $220 billion per year! The Irish Potato Famine of the 1840s is a historical example that illustrates the devastating impact of plant diseases on food availability. A fungus-like microorganism causing disease struck the potato crops, which were a vital food source for the Irish population, leading to widespread crop failure. Over a million people died from starvation and related diseases, and another million fled their homeland to escape the poverty and hunger. This tragic event highlights the critical importance of protecting our crops from pests and diseases to ensure **food security**. Today, more than 150 years after the Irish Potato Famine, pests and diseases still threaten the world's food supply. Although it is common for farmers to use chemical **pesticides** to protect crops, overuse of these chemicals can have harmful effects on the environment, animals, and human health. Additionally, many pests are becoming resistant to pesticides, making these treatments less effective. The world needs a better solution to protect crops and ensure food security without causing harm.

Interestingly, plants have their own natural defense systems, somewhat like the **immune system** in humans and animals [1]. Keep reading to learn how plants naturally defend themselves against pests and diseases, and how scientists might be able to use nature's own remarkable strategies to develop **sustainable** ways to combat these threats—protecting crops without relying so heavily on pesticides.

FOOD SECURITY

Having reliable access to enough nutritious food for a healthy life, without worrying about running out or not being able to afford it.

PESTICIDES

Chemicals used to kill or control pests like insects, weeds, or fungi that can damage crops and harm food production.

IMMUNE SYSTEM

The defense system that uses cells and proteins to fight off harmful invaders like bacteria, viruses, and other dangerous attackers to keep an organism healthy.

SUSTAINABLE

Using resources in a way that meets our needs without harming the environment or depleting resources for future generations.

HOW DO PLANTS DEFEND THEMSELVES?

Plants are not passive bystanders in nature; they have a variety of strategies to fend off the vast array of pests and diseases that they face daily (Figure 1).

All plants come equipped with some general, first-line defenses to resist attacks. These include physical barriers like the tough, waxy surface of their leaves, which acts as a shield to block out invaders. But

Figure 1

Plants are affected by many types of pests and diseases. Here are just a few examples: **(A)** insect pests called aphids on a leaf; **(B)** a fungus called corn smut on an ear of corn; **(C)** a water mold called downy mildew on a grapevine leaf; **(D)** insect pests called mealybugs on a corn plant; **(E)** a fungus called gray mold on a strawberry; and **(F)** a fungus called brown rust on wheat (figure credits: iStock).

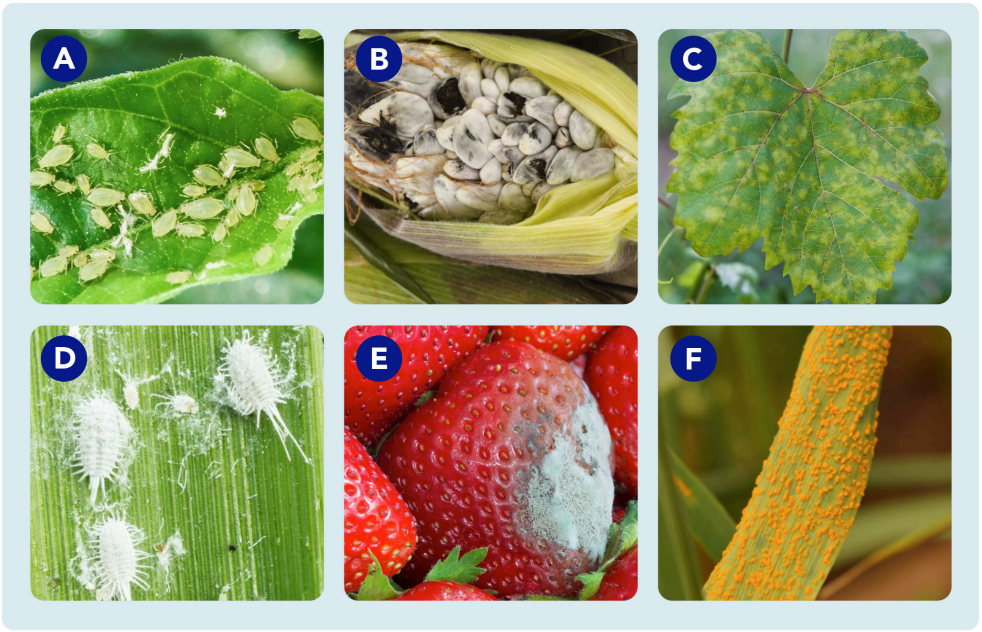

Figure 1

the protection does not stop at the surface. Inside, plants have a set of general chemical defenses that attack and destroy harmful microbes and insects before they can do serious damage. These responses are always ready to protect the plant from common threats. They are not tailored to any specific enemy—think of it like a security system that alerts a homeowner to any disturbance, big or small, without knowing exactly what caused it.

When these general defenses are triggered by invaders, plants produce various protective chemicals and proteins that actively fight off the attackers. For example, when a plant detects an invading insect, it might release bitter chemicals or sticky substances that discourage the insect from eating its leaves. Sometimes plants can release smells that keep insects away or that can even alert *other* plants that a threat is nearby [2]! But what happens when a stronger, more potent threat comes along? That is when a fascinating aspect of plants' natural defenses kicks in, called **induced resistance** (IR).

INDUCED RESISTANCE

Induced resistance in plants is when plants boost their defenses after being exposed to a threat, including both getting ready (defense priming) and becoming stronger against the threat.

INDUCED RESISTANCE—PLANTS ON HIGH ALERT!

Sometimes, especially when faced with an unfamiliar or particularly aggressive pest or disease, a plant's general defenses are not enough. IR helps plants to "ramp up" their defenses in response to threats, making them stronger and more resilient.

When a plant is exposed to a small amount of stress, such as a pest nibbling on its leaves, it does more than just enhance its defenses to deal with the immediate threat. Thanks to IR, plants

also have a remarkable ability to "learn" from these encounters. This fascinating process is called **defense priming**, and it works a bit like the human immune system. When you get a vaccine for the flu or COVID-19, for example, your body receives a small, safe amount of the disease-causing organism. Your body reacts and "remembers" this organism, so the immune system is prepared to fight off the real disease if it is encountered. Similarly, defense priming results in a kind of "memory" that helps plants to be better prepared for future attacks from the same or similar pests or diseases—so they react faster and more powerfully than before [3]. Yes—plants have a kind of "memory" about their past experiences!

DEFENSE PRIMING

The process by which plants use a form of "memory" to prepare and respond more quickly and strongly to future attacks by pests or diseases, enhancing their defense mechanisms.

IR in plants can be activated in two main ways. First, IR can be activated by a pest damaging the plant or by an infection. Like a vaccination, this first attack teaches the plant how to defend itself against future threats. IR can also be activated by helpful microbes in the soil that live near plant roots [4]. These tiny beneficial organisms prepare the plant's immune system to defend itself against a variety of pests and diseases. This method of defense priming is especially useful because it involves natural plant-microbe partnerships that improve the plant's defenses without the need for pesticides or other chemicals. IR activated either by pests or by soil microbes is considered **systemic resistance (SR)**, which means the protection extends to *all* parts of the plant—even parts that were not initially attacked, like leaves far away from the one that was nibbled.

SYSTEMIC RESISTANCE

When a plant strengthens its defenses throughout its entire system after a local infection or attack, helping protect against future attacks.

WHAT MAKES IR SO GREAT?

What if farmers could somehow harness plants' natural defense mechanisms to protect their crops against pests and diseases? IR has many benefits that could make it a great crop-protection strategy (Figure 2)!

First, IR has the potential to provide effective protection against many types of diseases and pests. By activating IR in crops, we might be able to reduce the need for harmful pesticides, promoting a healthier ecosystem. Even better, pests are less likely to develop resistance against IR, which means that this protection method could remain effective over the long term. IR could also be used to treat diseases and pests for which no pesticides or other chemical treatments are currently available.

Another amazing benefit of IR is that it can be passed on from "parent" plants to their offspring—and it might even stick around through many generations. This means that the plants farmers grow today could help them to protect future crops—just by planting seeds that already know how to fight off threats. This ability makes IR both a smart choice for today's farmers *and* a powerful tool for ensuring the health of crops for years to come.

Figure 2

IR has many benefits that can make it an effective crop-protection strategy.

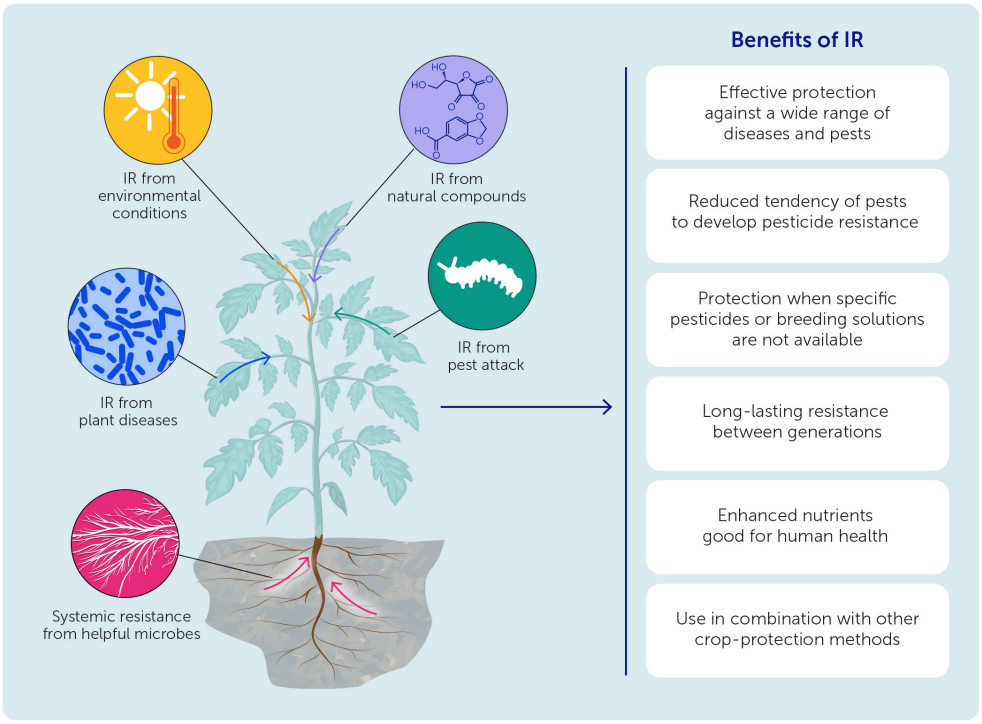

Figure 2

And there is more—when plants activate their natural defense mechanisms, they often produce a range of beneficial compounds, such as antioxidants and vitamins, which are health-promoting components of the foods we eat. By harnessing IR, we might be able to grow crops that are not only more resilient but also more nutritious, supporting healthier diets and stronger communities! With IR, the benefits could extend beyond the field, reaching the tables of families everywhere.

USING NATURE'S SOLUTIONS TO PROTECT CROPS

To protect crops using IR, the idea is to use certain signals or treatments to prepare the plants' defenses before any actual attacks occur. There are several ways to "switch on" IR in plants (Figure 3). One way is to use chemicals that can imitate the effects of a disease or pest attack. These chemicals can be applied to seeds, soil, or directly onto crops to activate their defense systems before pests or diseases strike. Another method involves using helpful microbes, such as certain bacteria and fungi, that can stimulate the plants' defenses [4]. Applied to plants or to the soil, these microbes can settle in the roots or leaves, providing constant protection against specific threats. As a side benefit, these microbes can also improve plant growth and overall health by providing nutrients and other substances that the plants need.

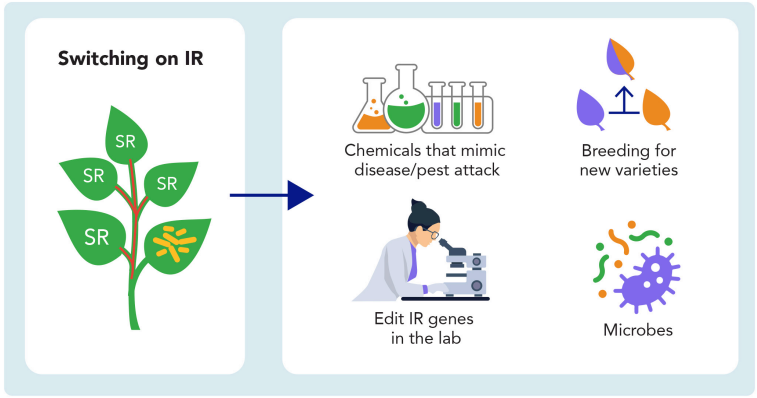

Figure 3

There are several ways to "switch on" IR in plants to create systemic resistance (SR). Switching on IR can be accomplished using chemicals that imitate the effects of a disease or pest, microbes that can stimulate the plant's defenses, breeding new crop varieties with strong IR traits, or laboratory techniques to manipulate or "edit" the plant genes involved in IR. SR protects all parts of the plant—even those far away from parts that were initially attacked.

Researchers are also exploring ways to make IR stronger. By identifying the key plant genes involved in IR, scientists may be able to develop new crop varieties with even better defensive capabilities. This work could involve plant breeding, in which plants with strong IR traits are selected and bred with each other over multiple generations, or it could involve laboratory techniques that directly manipulate the plant genes involved in IR.

ONGOING CHALLENGES FOR PLANT SCIENTISTS

While IR has many benefits, there are also challenges that still need to be addressed before it can be used to protect crops. One major challenge is balancing the plants' growth and defense. Activating a plant's defense system can sometimes slow down its growth because the defense system diverts energy away from growth processes. So, scientists are working on finding the right balance between enhancing defense and growth, so that plants can remain healthy and produce lots of food for us while still being well protected.

Another challenge is the variability in how well IR works, due to different environmental factors. The success of IR can depend on the type of plant, the specific pest or disease, and environmental conditions such as temperature and soil quality. Researchers are studying how these factors influence IR, and they are developing strategies to make it as effective as possible under various conditions.

CREATING A FUTURE OF SUSTAINABLE AGRICULTURE

Plants have amazing natural abilities to defend themselves against pests and diseases. By using IR, researchers could make agriculture more sustainable and help feed the world without relying so heavily on harmful chemicals. Even better, scientists have found that boosting plant defenses could also lead to healthier crops with more nutrients,

benefiting both people and the planet. This research holds great promise for the future of farming and food security.

IR will not eliminate the need for some pesticides, but it could greatly reduce the amounts of these dangerous chemicals that farmers need to use. Using IR in combination with other methods, such as breeding pest-resistant crop varieties and using beneficial microbes, may be an extremely effective approach to pest and disease management. This combined strategy not only enhances crop protection but also promotes biodiversity and soil health. As we continue to face challenges like climate change, growing enough food to feed the ever-increasing number of people on the planet might become even harder. Remember the Irish Potato Famine we talked about at the start? This historical event shows just how important it is to keep our crops healthy. By using nature-based ideas like IR, scientists can help plants protect themselves in a sustainable way. Hopefully, this means we can all look forward to a future where everyone has enough tasty fruits, veggies, and grains to eat, no matter where they live!

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REFERENCES

1. Ngou, B. P. M., Ding, P., and Jones, J. D. 2022. Thirty years of resistance: Zig-zag through the plant immune system. *Plant Cell* 34:1447–78. doi: 10.1093/plcell/koac041
2. Brilli, F., Loreto, F., and Baccelli, I. 2019. Exploiting plant volatile organic compounds (VOCs) in agriculture to improve sustainable defense strategies and productivity of crops. *Front. Plant Sci.* 10:264. doi: 10.3389/fpls.2019.00264
3. Mauch-Mani, B., Baccelli, I., Luna, E. and Flors, V. 2017. Defense priming: an adaptive part of induced resistance. *Ann. Rev. Plant Biol.* 68:485–512. doi: 10.1146/annurev-arplant-042916-041132

4. Pieterse, C. M., Zamioudis, C., Berendsen, R. L., Weller, D. M., Van Wees, S. C., and Bakker, P. A. 2014. Induced systemic resistance by beneficial microbes. *Ann. Rev. Phytopathol.* 52:347–75. doi: 10.1146/annurev-phyto-082712-102340

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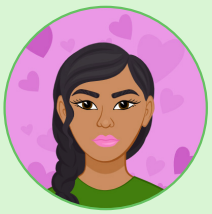

ARIANNA, AGE: 11
My name is Arianna and I am 5th grader at Rachel Freeman Elementary and a scientist at Young Scientist Academy. I like math and science and when I grow up I would like to be an explorer.

JAMARION, AGE: 10
My name is Jamarion and I am a 5th grade student at Rachel Freeman Elementary and a scientist at Young Scientist Academy. I really like math, soccer, archaeology, and science. I also like dogs and jaguars.

NOAH, AGE: 10
I am a 5th grade student at Rachel Freeman Elementary and Young Scientist Academy. I like to play soccer and on my PC. I love science because I can learn interesting things. When I am older I want to be a doctor so I can buy an expensive house and make people better.

ZURI, AGE: 10

My name is Zuri and I am a 5th grade student at Rachel Freeman Elementary and a scientist at Young Scientist Academy. I like to do theatre and I love sharks. When I grow up, I want to be a paleontologist and perform on stage. I speak English and Spanish.

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I studied biology and I was so fascinated by the phenomenon of induced resistance in plants when I first encountered it as a young student that my entire later research, as well as my teaching as a professor at the University of Neuchâtel in Switzerland, was dedicated to this subject. I really enjoy gardening, cooking, and reading science fiction books, but mostly spending time with my German shepherd Tiloup. *brigitte.mauch@protonmail.com

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Dr. Flors is a professor at the University of Jaume I in Castellon, Spain. He is a chemist by training and his research is focused on what happens in plants at the biochemical and molecular level when they defend themselves against pests and pathogens. He is a nature guy and loves hiking in the mountains and spending time with his dog and children.