

Scientists boost plants' natural immunity without hindering their growth

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Professor Miao Yansong of NTU with model plants in the laboratory, where they enhanced the plants' immune response using bioengineering methods. Credit: NTU Singapore



Researchers at NTU Singapore rearranged immune receptors in *Arabidopsis* and achieved around 53% less bacterial growth in infection tests

Writer: Camila Herrera R.

Editor: Karem Díaz S.

Scientists at Nanyang Technological University, Singapore (NTU Singapore), have developed a strategy to enhance the natural immune response of plants by precisely rearranging receptors on the surface of their cells. In laboratory experiments with *Arabidopsis thaliana*, the modified plants showed approximately 53% less bacterial growth than control plants, without the enhanced defenses affecting their normal growth.

The work, published in *Science Advances*, is based on synthetic protein engineering and addresses a central question for plant health: how to get a plant to detect the presence of pathogenic microorganisms more effectively and activate a more intense defense without permanently switching on its immune system.

This balance is especially important because an excessive defensive response can compete with plant development. Recent research has already shown how plants regulate the balance between immunity and growth, allocating resources to defense when they recognize a threat and regaining priority for growth when that response is no longer needed.

FLS2 receptors function as sensors against bacteria

The team, led by Professor Miao Yansong of the School of Biological Sciences at NTU Singapore, studied an immune receptor called FLS2, short for *flagellin sensing* 2. This protein recognizes flagellin, a component associated with numerous bacteria, and is involved in initiating the plant's defense response.

Receptors located on the cell surface function as a surveillance system. When they recognize certain patterns associated with potentially harmful microorganisms, they transmit a signal that activates the plant's defenses. The NTU research sought to

determine whether the physical organization of these sensors could be modified to achieve a more efficient response.

The agricultural relevance of these mechanisms lies in the fact that numerous pathogens have evolved precisely to evade, block, or manipulate immune surveillance. Studies on [proteins used by fungi and oomycetes to weaken crop defenses](#) show that the interaction between recognition and infection is one of the main areas of research for developing more resistant plants.

Two FLS2 receptors and two partners produced the optimal response

Using single-molecule imaging techniques and protein engineering, researchers tested different groupings of the FLS2 receptor and its associated receptors. The experiments identified a configuration consisting of two FLS2 receptors and two partner receptors as the arrangement that offered the best performance.

This organization reinforced the initial immune signal and, at the same time, allowed the receptors to be removed and replaced normally after fulfilling their function. The result was more intense surveillance without the need for extensive redesign of the plant's defense system.

The finding also revealed a significant limitation: indiscriminately increasing the number of clustered receptors did not improve defenses. When scientists concentrated too many receptors, they obtained a strong initial response, but subsequently hindered their renewal, ultimately weakening the ability to maintain the immune signal.

The accuracy of this response is crucial because the continuous activation of defenses can have physiological costs. Another strategy recently studied has enabled [a natural nematode pheromone to prepare crop defenses](#) against

different groups of pathogens without continuously activating the entire plant immune system.

The modified plants reduced bacterial growth by 53%.

Infection tests showed that plants with the enhanced immune system exhibited approximately 53% less bacterial growth than control plants, according to counts performed during pathogen trials.

The researchers also observed that the strengthened immune response did not produce a detectable alteration in normal plant growth under the experimental conditions. This point is relevant because one of the difficulties in transferring greater resistance to crops lies precisely in preventing the energy used for defense from reducing development or yield potential.

The ability to enhance the recognition of microorganisms is also being explored using other types of receptors. Previous research has identified plant immune receptors with the potential to amplify resistance against different pathogens , highlighting the importance of these proteins as tools for crop protection.

Arabidopsis serves as a first model before moving on to food crops

The experiments were conducted using *Arabidopsis thaliana* , a species in the Brassicaceae family widely used as a model organism in plant biology. Its genetics and cellular processes are extensively characterized, allowing the study of mechanisms that can later be investigated in agricultural species.

The receptor rearrangement principle could be adapted in the future to leafy vegetables belonging to related groups, including Chinese cabbage, kale, chye sim,

and kai lan. However, the team cautions that each crop will require specific research to identify its receptors, determine the appropriate configuration, and experimentally verify that the modification provides effective protection.

Therefore, the results obtained with *Arabidopsis* do not mean that a commercially available technology for crop protection is yet in place. The study constitutes an experimental demonstration of the mechanism, and it will still be necessary to verify its performance against different pathogens and under larger-scale production conditions.

The differences between species and pathogens make this validation especially important. In soybeans, for example, a gene related to natural defenses against *Fusarium oxysporum* has been identified , but these results also require progressing from molecular characterization to agronomic verification of resistance.

Resistant seeds and treatments for established plants

The study used genetic modification to introduce the enhanced receptor configuration into the plants. However, scientists are also working on alternatives that would allow them to harness the same principle without relying exclusively on genetically modified plants.

One possibility is to develop varieties and seeds with an enhanced capacity to recognize pathogens. Another line of research involves designing stimulants that can be applied directly to established crops to temporarily improve their immune response to diseases.

This second approach would broaden the agronomic possibilities of the research, although it is still under development. Scientists will need to determine whether it is possible to externally induce the appropriate configuration of the receptors and

maintain a sufficiently intense and long-lasting response under agricultural conditions.

Harnessing the plant's own defenses is already being studied using various strategies. One of these has explored compounds capable of acting similarly to a [chemical "vaccine" that prepares plants against pathogens](#), showing that the targeted activation of immune mechanisms can become a complementary approach to disease management.

Two technologies derived from the study are in the patent process

The team has filed patent applications, through NTUitive, for two technologies used during the research. The first is a method for synthetically engineering proteins that allows researchers to control how receptors cluster on the cell surface and determine which arrangement produces a stronger and more sustained immune response.

The second is a live-cell imaging and analysis platform designed to measure how many individual receptors have assembled on the surface of a plant cell. The combination of both tools made it possible to observe the behavior of immune sensors and relate their physical organization to the intensity and duration of the defensive response.

The researchers now plan to expand their work to leafy vegetables and other high-value crops suitable for indoor farming systems. They will also need to assess whether the enhanced immunity remains effective against different microorganisms and when the plants are moved from controlled experiments to larger-scale production conditions.