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Can a spray make our crops better?

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Abstract

UPPER READING LEVEL

Did you know that the first genetically modified crop was a tomato with delayed ripening? Genetically modified organisms (GMOs) have been around for decades now. And they offer a lot of benefits, such as an increased food supply, resistance to diseases, and more. Yet there are a few downsides as well. Producing them takes a lot of time and is often expensive. Plus, many people have concerns about their safety, since they include foreign DNA in their genome. But what if we can alter the crops without changing their genome? We tried using bioactive molecules which can change cell activity. To insert them into the plant cells we tested sprays with nanocarriers. It turned out to be a success! Many nanocarriers were able to penetrate the plant cells. We also successfully inserted bioactive molecules in the cells through spraying. In this way the cell could express a new gene or silence an existing one.

Introduction

You have probably heard of **genetically modified organisms** (GMOs). But do you know how scientists make them? It usually takes 4 steps:

1. They look for a trait that can improve the organism. For example, a desirable plant trait could be disease or drought resistance. Then they find another organism that already has that trait and locate the **DNA** responsible.
2. They copy the desired DNA. Often scientists use bacterial cells to produce a lot of DNA copies.
3. They insert the DNA into the organism they wish to modify. Sometimes they use bacteria to infect the cells. Other times, they use metal particles coated with DNA. The result is that the desired DNA integrates into the **genome** of the GMO. This modified genome then **expresses** different **genes**, leading to the desired effects. The modified genome also carries on to future generations.
4. Finally they grow the new plants that are resistant to diseases, drought, insects, etc.

We can't deny that GMOs can be very helpful. But there are some downsides. For instance, GMOs take a long time to make and the production can be quite expensive. Another issue is that many people consider them harmful to our bodies and the environment.

So, what if we can modify the plant to have the desired traits without altering its genome? So that it won't take so much time to produce and it would be cheaper? And much easier to do? This is what we wanted to achieve.

Methods

Bioactive molecules (for example, hormones, DNA, or RNA) can interact with cells and adjust their activity. So, instead of changing the plant's genome, we can insert such molecules to control the cells. It sounds simple enough, but achieving it is no easy task. Plus, we wanted an easy application method that people can use in agriculture. We decided to try delivery through sprays.

We considered different **nanocarriers** that can insert the bioactive molecules into the cells. We settled on **cell-penetrating peptides (CPPs)**, since they can target specific **organelles** inside the cell.

We performed three separate experiments.

Experiment 1: We wanted to figure out which CPP would be the best at entering plant cells via spraying. For this purpose we tagged various CPPs with fluorescent yellow dye. Next we sprayed this complex (CPP plus dye) on the plants' leaves. We then measured the fluorescence with a special microscope.

Experiment 2: We wanted to test if these nanocarriers could insert DNA and **RNA** into the cells. So, we combined CPPs with a **reporter gene system** and sprayed another group of plants (Figure 1). If the DNA penetrated the plants' cells, they would express its genes and we would see blue spots.

Experiment 3: We wanted to see if we could **silence** some genes, because this can be as important as inserting new ones. As a test subject we used a genetically modified plant that expresses yellow fluorescence (glows yellow!). We sprayed this plant with a nanocarrier combined with a small RNA molecule that should interfere with the expression of fluorescence – without changing the modified genome. Success would mean no or decreased fluorescence.

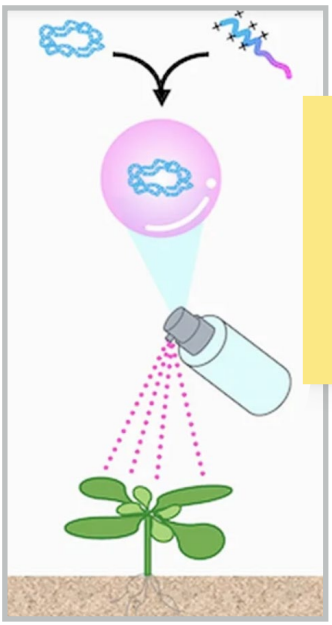


Figure 1:
Spraying the leaves with a nanocarrier with bioactive molecules (DNA or RNA).

Results

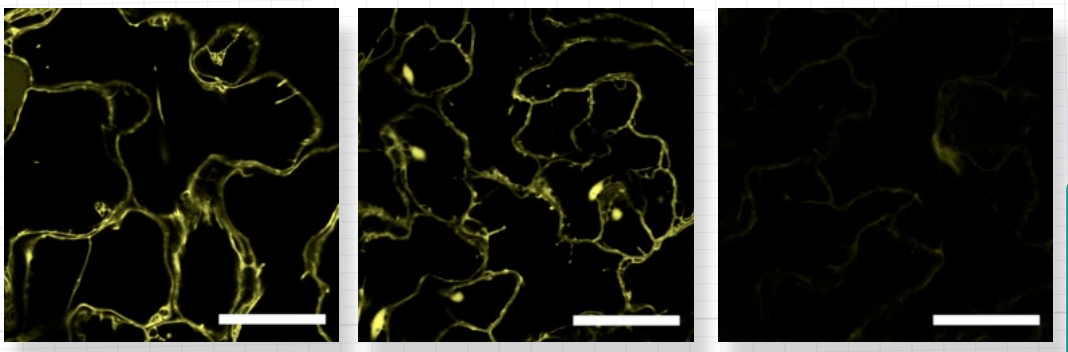
Our experiments showed us that:

1. Various CPPs showed different fluorescence intensities after we sprayed them on the plants' leaves.

2. There were blue spots after we sprayed plants with the combination of nanocarriers with DNA.

3. Spraying the genetically modified plant with the nanocarrier/RNA combination resulted in reduced fluorescence. In contrast, spraying it only with the nanocarrier or the RNA didn't reduce the fluorescence. (See Figure 2.)

Fluorescence of yellow fluorescent protein



NANOCARRIER RNA COMBINATION

Figure 2:
Microscopic images of the yellow protein's fluorescence after spraying the genetically modified plant's leaves with
1) a nanocarrier
2) a bioactive molecule (interfering RNA)
3) a combination of both of these.

Why is there fluorescence in the first two microscopic images? And why is there hardly any fluorescence on the third image?

Discussion

Our results are quite promising! Spraying bioactive molecules on the plants' leaves is an efficient delivery method. Many natural CPPs were able to enter the leaves' outer layer. The nanocarriers were also successful at delivering DNA molecules into the cells. Observing the fluorescence after this delivery means the cells express the new genes.

Moreover, we were able to silence other genes. This means that the bioactive molecule (RNA) blocks a gene. In our case, the RNA blocked the gene expressing the fluorescent protein. Thus, the genetically modified plant, which usually glows, emitted a lot less fluorescence.

Conclusion

We developed a way to modify plants without changing their genome that is both safe and very easy to apply! Plus, it takes a lot less time and money! This doesn't mean we should ignore GMOs, though. Do some research to find out what genetically modified crops are grown in your country. What are their benefits? What about their drawbacks?

Glossary of Key Terms

Bioactive molecules – various molecules, like hormones, growth factors, DNA, and (small) RNA, which can interact with a cell and change its activity. For example, tannins can have antioxidant effects.

Cell-penetrating peptide (CPP) – a type of nanocarrier that is a short peptide (chain of amino acids). They facilitate the intake of molecules inside the cells.

DNA (DeoxyriboNucleic Acid) – a molecule that carries the genetic information used in the growth, development, function, and reproduction of all known living organisms, including humans.

Expression (genetic) – the process when a gene gets turned on to make RNA (and then proteins).

Gene – a small section of DNA with the instructions for characteristics of the organism.

Genetically modified organism (GMO) – an organism whose genome has been changed intentionally (in the lab).

Genome – all genetic material in a cell or organism. The genome consists of DNA.

Nanocarrier – a very tiny (1-100nm) material that can transport other substances, such as bioactive molecules, and drugs.

Organelle – a special subunit within the cell that has a specific function. For example, the nucleus in eukaryotic cells contains the DNA and controls all activities in the cell.

Reporter gene system – a technique that shows if a gene is expressed. In our case we used a gene that codes for fluorescent proteins.

RNA – short for RiboNucleic Acid, a nucleic acid present in all living cells. It can act as a messenger carrying instructions from DNA for the synthesis of proteins. RNA molecules can also switch on and off the expression of other genes. This is called RNA interference (RNAi).

Silencing (gene silencing) – regulation inside the cell that prevents (switches off) a gene's expression. It can occur during either transcription or translation.

Check your understanding

1. What is the difference between genetically modified organisms and altering cell activity through bioactive molecules?

2. What did the reduced fluorescence in the third part of our experiment show us?

3. In our experiment, we silenced the gene expressing fluorescence, not a very important trait. Can you think how gene silencing can be useful?

4. Resistance to drought and diseases are two examples we gave for positive traits desired in crops. Can you think of any others?

5. Do you support GM crops? Why or why not? Consider how they have helped to address global hunger as well as the risks they present to humans and the environment. Discuss this in small groups in class, or do some research online!

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