

Biotechnology: Can it help in making the desert green.

Hi. My name is Ziad Jaradat. I'm a faculty member of the Jordanian University of Science and technology. I'll be talking to you today about a fascinating science. But before I start talking, I would like to ask you this question, what are the major problems facing the world these days?

Some of you might say food shortage, others might say environmental pollution, while a third to group might say energy crisis. The list goes on and on and on. All of these are real problems facing the world these days. However, we will be focusing on one of these problems, which is the food shortage that touches the life of every single person in the world.

In fact, more than 90% of the Jordan land is desert. And by far Jordan is considered one of the poorest countries in water resources in the world. This table shows the distribution of land in Jordan based on the suitability for agriculture. As you can see, dry or semi-dry areas compose about 93.3% of the total area in Jordan. Urban area, around 1.89%, forest and agriculture land around 4.19%, and water surfaces cover only point. 62% of the Jordan land.

Just to make the picture clearer, and to have an idea of what these numbers mean, the distribution and land use in Jordan is depicted in the following map. As you see here, this yellow area represents the dry area. The orange represents the semi-dry. So basically, most of the Jordan land is dry or semi-dry. Only this green zone, the small area in the northern part of Jordan is green, with some vegetation and, of course, the urban land's located in this area.

In case someone is not convinced of this distribution, here's a true picture of Jordan taken from a satellite. It shows the narrow zone of vegetation, with the majority of the land being desert or semi-desert. As you can see in this map of Jordan, all this area is dry or semi-dry, with only this narrow zone containing agricultural land and vegetation.

Let's go and see the real desert in Jordan and have a picture of what type of plants grow there, and see if we can feel its harsh conditions. Now I want you to look around and see if we can come up with answers for the following questions. Do we see plants in the desert? Do you think that these plants need as much water as the non-desert plants? How can they survive the hot and dry conditions in this desert? And how can we utilize these plants to grow non-desert plants in this area? Now I will leave you for two minutes to discuss these questions, and I'll be back.

Welcome back. Now we have seen the desert and its plants. Can you think of a method to make this desert greener and to solve some of our food shortage problems at the same time? I guess there is a possibility. That's why I'll be talking to you today about a fascinating science that's called biotechnology, which is a mixture of different divisions of sciences including microbiology, biotechnology, molecular biology, biochemistry, and some of other sciences.

Before the birth of this science, what our ancestors used to do to produce plants for superior quality that they would not have had otherwise? Plant breeding holds the answer for this question. Plant breeding's about hybridizing different plants with the desirable traits from different varieties to produce new plants of superior quality.

This approach to improve crop production has been very successful with plants like wheat which is an extremely important agriculture commodity that has been domesticated for thousands of years. It was made suitable for human consumption by selective breeding and hybridization with other closely related species, or with different varieties from different parts of the world. Example, crossing wheat species that have a thin hull with wheat species that can endure harsh conditions such as extreme cold or hot.

The following is a classic example describing an experiment of wheat breeding. We have three types of wheat. AA, diploid domesticated wheat with unequal 14, which is fourteen chromosomes. BB, diploid white type wheat, also has fourteen chromosomes. DD, another diploid white type wheat with fourteen chromosomes.

When we cross two wheat types of wheat, A with B, we get AA BB which is a tetraploid type of wheat containing 28 chromosomes. It has a modified quality, but not the desired one. So we take this type, or the tetraploid wheat, and cross it with a third type of wheat, which is DD. Now we get 42 chromosomes. This is called hexaploid domesticated wheat.

Unlike the diploid and tetraploid types of wheat, this type of wheat is used to make leavened bread and has a superior quality compared to the original wheat.

Traditional breeding was not only practiced on cereal grains. Fruits also were enhanced by breeding. An example is the hybridization of the strawberry. The modern strawberry sold in most stores with their large fruit are hybrids between two other species from different parts of the world.

Now I will ask you a few questions to think of during the break. I want you to get a piece of paper and try to write down the answers to these questions. What are the major problems with plant breeding? How long will it take to obtain the desired traits or desired plant with the desired crop? Can we breed all types of plants? Are we always getting the traits that we want? I'll leave you for two minutes. I'll come back.

Welcome back everyone. I guess you have thought of some of the problems of the traditional plant breeding, such as the long time it takes to obtain a desirable trait, and desirable traits that you might have in the new product, only sexually reproducing plants can be bred in this way.

Let's see what my technology can offer us as an alternative. Plants are the ideal living organisms to use in biotechnology, as you can produce a whole plant from a single differentiated cell, which is called a totipotent cell. Plant biotechnology, therefore, is about manipulating plant genetic material, or the DNA, by transferring and combining genes from different plants to produce new plants with better characteristics.

To produce this genetically modified plant, the following simple steps have to be done. First, to identify the genes exclusive to the traits such as drought resistance. Amplify the identified genes. Transfer the amplified genes into the plant cell. And grow the cell, which will give a whole new plant with the new desirable traits that's called transgenic plant.

The question is how to introduce the new genetic material, or the DNA, into the plant cell. There are several different techniques used to introduce the desired genes to the plant cell. Some of these methods are biological, while others are physical.

Biological methods, one of these methods to transfer DNA into plants take advantage of a bacteria called *Agrobacterium tumefaciens*. This bacteria naturally infects the plants and injects its DNA into the plant cell, forcing the plant to create a suitable environment for the bacterium to live. Scientists were able to introduce the desired genes into the bacterial genome and just allow the bacteria to infect the plant cell. This allows the introduction of the new genes into the cell, which will be grown to give a whole new transgenic plant.

The following diagram shows this process. This diagram represents the bacteria which is called the *Agrobacterium tumefaciens*. It has a piece of DNA called the circular DNA, or plasmid. This plasmid would be extracted from the cell. It will be cut with a restriction enzyme. And we will introduce the gene, or the foreign gene, into this plasmid.

We will ligate it with a ligase which is like a ceiling. And then we re-introduce this plasmid into the bacteria again and allow this bacteria to infect this cell. Once the DNA is inside the cell it will be integrated with the plant cell genome and when we grow this cell it will grow to produce a whole new plant which is called a transgenic plant.

As for the physical methods, microscopic gold beads are coated with the DNA containing the genes of interest and are shot into the plant cell with a burst of helium using an instrument called the gene gun. Once inside the cell, the genes come off the bead and integrate into the genomes of the cell. Again this cell will be propagated to give a whole new plant with new traits.

This schematic diagram shows the gene gun and how it works. This is a schematic diagram of the gene gun and this is how it works. We have here a cartridge holder that contains the DNA-coated gold beads. We have a helium cylinder that will push these gold beads into the gun barrel, where they will enter the cell.

By now, we have known the methods of introducing genes into the plant cells. During this break, I want you to think and combine a list of all the desired traits that you would like to see in the new plants. I'll see you in two minutes.

Welcome back. As you have seen, in the desert there are lots of shrubs and small plants that can grow without producing any crop. We can take these plants, study their genetic material, and find the genes responsible for their resistance to dryness or salt concentrations.

Once identified, the genes will be transferred to regular non-drought resistant plants that produce beneficial crops using one of the previously mentioned methods of gene transfer. The genes will confer new traits on new plants, thus enabling the newly-transformed plants to withstand dryness or high salt concentration. And they might produce beneficial crops at the same time.

If plants with the new traits are successfully produced then the desert can be planted with other types of plants, non-desert plants, that otherwise cannot grow there. This will increase the vegetation and at the same time might produce beneficial crops.

Now let's go back to our classic example, the wheat. It is a crop that cannot be grown in desert semi-desert area as it needs a high amount of water. Thus the wheat crop is dependent on the amount of rainfall each year. If we manage to transfer anti-drought genes from the desert to the wheat, we would be able to enlarge the area of land cultivated by wheat. Not only that, the crop will be consistent, as the new genes will minimize the effect of load and fall on the crop.

The benefit of this type of technology will be minimizing the shortage of food, slowing down desertification, and might increase the amount of rainfall in the areas, especially if large transgenic trees are grown in the desert area. This will be reflected on increasing the total green area in the country, and increasing the food production at the same time.

The following picture shows deserts can support heavy plant growth, even with its limited water resources. This picture was taken by one of my colleagues in Jordan desert called the Wadi Rum. This picture shows a type of a grass similar to wheat that grows in the desert with a minimal amount of water. If we identify the genes that enable the plant to grow in this area, we can transfer them to wheat. Then we would be able to grow wheat in the desert or semi-desert area.

Now plant biotechnology is not all about solving problems of dryness or salinity, or making the desert green. How can we utilize biotechnology to produce superior vegetables or fruits? How can we solve some health problems, such as malnutrition, utilizing plant biotechnology? Can we enhance the storage conditions of highly perishable vegetables or fruits? We will take a short break. During this break, I want you to come up with answers for the above questions and to list other applications of plant biotechnology that you want to see in the future plants. See you in two minutes.

Welcome back everyone. One of the major enemies of plants is the pest population that lives on these plants and sometimes damage the crop, or even the plant itself. Spraying pesticides is not effective all the time due to multiple problems, ranging from low effectiveness, to the high toxicity of these pesticides, to the accumulation of these toxins in the soil for a long time.

Can we use biotechnology to solve these problems and find alternatives to using these damaging pesticides? The answer to this question is yes. Plants can be engineered to produce a toxin in their leaves or roots. These toxins can specifically affect insects, but not the human or animal consumers. The toxin will be engineered to be only effective after certain treatments, such as the alkaline conditions and the certain proteases in the insect guts, where the toxin will affect only the insects, but not that the other creatures.

Traditional herbicides does not discriminate between crop and wheat, which limits their usefulness. A gene for herbicide resistance can be introduced in beneficial plants, making them resistant to certain herbicides, while wheat we will not have these genes. And this will be killed after spraying this herbicide.

Production of plants resistant to bacteria or fungi can also be accomplished by following the same principles. For instance, plants might be engineered to produce an enzyme such as chitinase, that degrades the chitin, which is a polysaccharide in the cell wall of the fungi, leading to the cell wall damage and eventually to the damage or the death of this fungi.

After all this talk about biotechnology and what it can do for us are you convinced that we can make the desert green and eventually help solve some of the food shortage problems? As you might know by now, these are not the only applications of biotechnology. Environmental pollution, which was mentioned at the beginning, and the energy crisis, can also be solved by biotechnology. And I will give you a question to take home with you. DO you think that you we use biotechnology to produce fuel from agriculture products always?

I hope you enjoyed learning about this amazing science and what it can do for us. At this point, I wish you all good luck in your studies, and goodbye.

My dear colleagues, thank you very much for considering the biotechnology module for your class. I hope you and your students enjoyed the module. The module is targeting the high school students who have some knowledge in biology. However, it stimulates the students to think of the questions asked at the end of each segment.

This module talks about biotechnology which is not given in schools as a class. Therefore, students have to think and come up with possible answers for the questions at the end of each segment. In the first segment, we will visit the desert area and show the students pictures from there, and ask several questions.

Do you see plants in it the desert? Of course, yes, there are some plants and shrubs. Do you think that these plants need as much water as the non-desert plants? No. How can they survive the hot and dry weather conditions? They must have some genes that enable them to live in harsh conditions. How can we utilize these plants to grow non-desert plants in the desert area? By transferring the genes that are responsible for the resistance of these plants to live in the desert area to the non-desert plants. And that simply was the main theme of the module.

Before the beginning of the second segment, the teachers can listen to the students answering these previous questions about the desert, and then can start the second segment. In the second segment the students will be introduced to the traditional breeding methods, with wheat being the result of this breeding.

The teacher can ask them about the problems of using the traditional methods, such a discussion should stimulate them to learn about the modern methods of plant manipulation. These problems are the long time it takes for the breeding, the undesirable traits that might be noticed in the new plant, and only sexually reproducing plants can be bred this way.

In the third segment, the students will be introduced to the methods of making transgenic plants. and will be asked to think of the main question that was asked at the beginning of the module. Which is, can we use this technology to make the desert greener? The teacher asks the question again, and see what kind of answers they will come up with after knowing all this about biotechnology.

And, of course, he has to see what kind of traits that they want to see in the new plants. Which is basically they should start thinking of what kind of genes they should transfer from the desert plants to the other plants. Some genes could be pesticide resistance, herbicide resistance, bacterial resistance, viral resistance, cold resistance, warm resistance. And in terms of products, they could think of better quality grains or fruits, damage resistance, or more nutrients, et cetera.

In the fourth segment, students will learn that traits other than dryness and salinity can be transferred to the plants. And they are asked to think of using the biotechnology to modify regular products. And what are the genes of the traits that can be introduced to enhance products? And they are actually asked to think out of the box, and see if we can use plant biotechnology for medical purposes. Like, for example, of introducing the gene of beta carotene, which is a precursor vitamin A, to rice, so that this fortified rice would minimize night blindness in poor countries. If we notice here that rice with beta carotene has already been produced, and it's called golden rice.

Finally, the students will be introduced to different applications of biotechnology that funnels to the main theme of the module. Which is making the desert greener by combating insects and fungal diseases. And at the end, students are left with a big question. Now you have seen the use of biotechnology in agriculture. Can we use it to solve other problems, such as the energy crisis, that we asked at the beginning of the module?

We welcome your feedback. Please feel free to contact me at jaradat@just.edu.jo . If you have any suggestions or criticisms, I welcome that.