

Sue Nelson

Hello, I'm Sue Nelson and welcome to the Create the Future podcast brought to you by the Queen Elizabeth Prize for Engineering, celebrating engineering visionaries, and inspiring creative minds.

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Plant geneticist Professor Pamela Ronald specialises in studying genes that can help make plants more resistant to disease and stress, especially rice, which is a primary nutrient source for more than 3 billion people around the world. Based at the University of California, Davis in the US at the Department of Plant Pathology and Genome Centre. She's also a member of the innovative Genomics Institute at UC Berkeley, a key scientist at the Joint BioEnergy Institute and a faculty affiliate of the Centre on Food Security and the Environment at Stanford University. Pamela, welcome to the podcast, a very impressive array of titles. So I feel slightly embarrassed, but I am going to start with a very basic question. Lots of people enjoy engineering and listen to this podcast, but they might not necessarily know how you genetically engineer plants?

Pamela Ronald

Well, thanks, Sue. It's great to be here. There are many ways of engineering plants and one way to do it is take a gene from one species, that doesn't even necessarily have to be rice, and put it into rice. And that's sort of classical, what we call classical genetic engineering. But there's many other ways to edit genomes, change genomes, conventional breeding where you do cross pollination, there are methods of genome editing now that make changes in the genome. There are sort of DNA guided methods for mixing genes in different varieties of a plant. So, there's really an array of tools for engineering plants. The process of taking a gene from one organism and putting it into another was devised by a naturally occurring soil bacterium called *Agrobacterium*, which moves some of its genes into plants. And it was that observation by Mary-Dell Chilton and others that really launched modern genetic engineering about 35 years ago. Scientists can put any gene they're interested in into the bacterium and the bacterium does the delivery.

Sue Nelson

Now, why do we need to genetically engineer plants when, as you've mentioned, you know, people have been breeding plants conventionally for specific traits for years?

Pamela Ronald

Well, there's many challenges faced by farmers and consumers. Of course, we have still, many, many people, young children that are that are malnourished don't have access to food, we have farmers that don't have food security, it may be that there are environmental stresses such as floods, or heat, drought. And these stresses are predicted to occur with greater duration and frequency as the climate changes. I think most people understand sort of this very interesting and sometimes devastating interplay between pathogens such as viruses and their hosts, which can be humans, or in the case of agricultural scientists, plants.

Sue Nelson

So give me an example then with rice, what are the main challenges for crops failing when it comes to growing rice?

Pamela Ronald

Well, rice farmers, like all farmers have a variety of approaches that they use, and of course, a variety of challenges. And one project that I've been fortunate to be involved in is developing a flood tolerant rice. And so rice grows well in standing water, but if it's completely submerged for more than three days, most rice varieties will die. And so, this has been a recognised problem by farmers for many, many years. And it's estimated that 4 million tonnes of rice, enough to feed 30 million people, is lost every year to flooding. But happily, at the International Rice Research Institute in the Philippines, scientists there have amassed a collection of 100,000

different types of rice varieties. And they had looked through this incredible genetic diversity looking for traits such as flood tolerance. And many years ago, maybe 50 years ago, scientists there found an ancient variety that had really an amazing property, it could withstand two weeks of flooding. And then when the flood was gone, it could start to grow again. And so, with conventional breeding, breeders tried to bring that trait into varieties grown by farmers today. But the farmers rejected those varieties, because in conventional approaches, you don't have very much control. So in conventional breeding, they brought in a lot of other traits that the farmers didn't want. So, it changed the flavour, the yield, things like that. So about, I guess, about 20 years ago now, my colleague David Mcil and I decided to try to isolate the gene using modern genetic techniques. And then we were able to find a gene that conferred two weeks of complete submergence. And then at the International Rice Research Institute, they developed varieties carrying this gene, and it was very, the new varieties carry just a small amount of that ancient variety, including the important trait. And so, the new varieties confer 60% yield advantage over the older varieties after flooding. So, this has been a very successful international project. Last year, more than 6 million farmers grew this tolerant rice.

Sue Nelson

Does it take on average sort of 1015 years for that to happen? Or can it be done in a, in a sort of shorter timescale?

Pamela Ronald

Yeah, it absolutely can be done on a shorter timescale, we were a little bit slow. And also, when we began our project, we didn't have the rice genome sequence. And once you have a genetic sequence, a lot of the different techniques along the way can be accelerated. And just to give you an idea, when I started my work it, it was something like \$70 million to sequence the Arabidopsis genome, which is this tiny little genome. And today, that same project can be carried out in about two days for \$1,000. So that's just a window into how fast genetics has been accelerating. And sequencing is one of the tools that we that we can use. So, scientists now not only have the sequence of one rice genome, but we have the sequence of 3000 rice genomes, and each of those genomes brings a wealth of genetic diversity that scientists can mine for really useful traits that will be useful to farmers and consumers.

Sue Nelson

And is it a similar process when you're looking to protect a particular plant variety from a certain disease or virus?

Pamela Ronald

Yeah, there are many ways, so this approach used a combination of marker assisted breeding, which is sort of a DNA fingerprinting approach. Scientists can bring in other types of traits such as resistance to disease or resistance to pests using these same kinds of techniques. But there are other techniques that are useful as well. And for example, one of the really useful traits for pest resistance is a gene that has been brought in from a bacterium. So this is the Bt trait and there's a bacterium called *Bacillus thuringiensis* and this is a bacterium that has been used by organic farmers for 50 years to spray on their crops, because that protects from some insect pests. But in places like Bangladesh, they don't have access to the sprays, they're very, very expensive. And often the sprays don't prevent the insect from getting inside the plant. So, what scientists have done, Bangladeshi and Cornell scientists took that gene from the bacterium and inserted it directly into the crop. And in this case, it was eggplant. And so now for the last five years, farmers in Bangladesh have been growing what we call Bt eggplant. And they've virtually eliminated the need to use chemical insecticides. So that's another really useful approach is taking genes, in this case, that bacterial gene and putting it into the crop.

Sue Nelson

It's quite interesting, you point out that effective positive benefit of using genetic engineering there particularly when there has been criticism and a lot of resistance from many environmentalists to the use of genetic engineering. But in fact, one of the benefits being that actually reduces insecticides, which is something that again, environmentalists have also wanted. And I was really interested to find out that your husband is an organic farmer. And you've actually written a book together called tomorrow's table organic farming, genetics and the future of food. So, I wondered how you reconcile organic farming, his livelihood with your scientific approach with genetic modification, sort of both on a professional and personal level, perhaps?

Pamela Ronald

Well, it's not that hard, because we have the same goal, which is to produce food without destroying the environment. And we both care a lot about food and farming and consumers, both here and in less developed countries. And it's really one of the biggest challenges of our times. And so we view farming from the framework of sustainable agriculture. And that means sort of a socio-economic lens as well as an environmental lens. So what we hope to do globally is to provide adequate food and nutrition for everybody in the world. And so that means that the poorest farmers in the world will have access to the seeds and the practices they need to produce enough food for themselves and their family. And sustainable agriculture also means reducing inputs, that includes chemical inputs, and also to conserve land and water. So much of the arable land around the world is already in use. And so if we can farm more efficiently, we can use less water and without clearing more land for farming, then it's also important to enhance soil fertility whenever you can. And so there's sort of a whole array of aspects of farming that are very important. So it's really difficult to generalise about the best way to farm. And so what, what we think about is, well, all farmers need access to seed, which is an important aspect, everybody grows some type of genetically improved seed. And so that's where the genetics come in. And then for the farming practices, it's really important for farmers to have knowledge about crop rotation, for example, perhaps alternative methods of pest control. So there are many aspects of farming that I've learned a lot from him, and hopefully he's learned a little bit from me too.

Sue Nelson

And how do you overcome people's reluctance to genetic engineering of food? Because when you hear you speak, you see, as you say, how many, if not all of your goals overlap with the aims of organic farmers?

Pamela Ronald

Yeah, so I should say, organic farming. The National Organic Farming programme in the United States does not allow farmers to use many modern seed technologies, for example, they're not allowed to grow Bt corn. So Bt corn carries a gene from a bacteria so farmers don't have to spray insecticides. So organic farmers are not allowed to do that. And in California, they'll try to spray the BT, but it's not 100% effective because the worms still grow on the tip. And so what organic farmers do as they cut off the tip and throw it away, so there's quite a bit of food waste, at least with sweet corn in California. So there are differences. I mean, really the major differences, organic farmers are limited and access to modern genetic tools. I think that there's of course, a lot of sort of chatter, internet chatter about food and farming and a lot of misinformation. And of course, as we all know that the misinformation can be very damaging to human health and the environment. And I think that it's pretty nice to talk one on one with people, because then you can try to understand what their concerns might be about modern genetic techniques. And I think giving specific examples is really useful. So I like the Bt eggplant example, because I think many of my friends in the United States are not thinking about farmers in Bangladesh, and they're not perhaps understanding the massive amount of chemical insecticides that are sprayed and just to understand that there is a genetic tool that will eliminate the need to spray chemical insecticides. I think it's very powerful for people to hear specific examples. The FDA does not, in the United States, the Food and Drug Administration, does not use the term GMO because it's so vague, because everything we eat is genetically improved. And, and I think that it really limits discussion if we talk about GMOs

being good or bad, because first of all, the term GMO means different things to different people. So I find that talking about specific examples is really, really useful. We know that it will be an ongoing challenge to try to get accurate information to consumers. And consumers are curious about food and farming, which is great.

Sue Nelson

And where do you see the greatest role, genetic engineering playing in agriculture in the future, particularly as the climate changes, I mean, you've given this great example with rice and flooding. And obviously, with sea level changes and the effects that we get on extreme weather, you can see immediately how that will help. But are there other areas that are also going to be at play here, where food security in particular will need the help from genetic engineers like yourself?

Pamela Ronald

Yeah I think it's really an ongoing challenge. So we have a really 10,000 years of domestication and there's different genetic techniques that are used as we go along with timeline to the present. Currently, there's a lot of interest in genome editing, which is a new tool that was developed almost 10 years ago, and allows scientists to make small edits in a gene and that can be also useful for these stresses that that we've talked about. There's a lot of interest, renewed interest in taking ancient varieties, plants that we don't really eat. Because so if you think about the food we eat, something like 70% of the calories consumed in the world comes from about five crops that have been domesticated over 10,000 years. So it's taken a very, very long time. And there's interest now in going into other sort of orphan crops or crops that aren't grown widely, and trying to domesticate them. And so one reason we don't eat some of the wild types of tomatoes that we see out in the world is because they might have some kind of toxin, or they might not produce enough fruit, or they don't behave well in a farm. So they might like send their fruits off, before the farmers farmer can harvest them. So, there's a lot of interest in trying to look more widely at different types of plants, and then doing small edits so that we can domesticate the crops more quickly. And so for a specific example, some colleagues have identified a wild species of rice that is very tolerant of salt, but no one grows it because it tastes terrible, and the seeds are small. So maybe what we could do is try to identify flavour genes, kind of tinker with them a little bit to make the grain taste better, perhaps we can tinker with some genes to allow the grain to stay on the plant before the farmer can harvest it, we can perhaps get that plant to produce larger grain. So in that case, you're starting with a plant that's salt tolerant, and you're adding in these domestication genes. And that's the opposite of what we've been doing now. Now, what we've been doing is we take a rice plant that has been domesticated over 10,000 years, and then we try to add back genes, like flood tolerance, so it's a sort of the opposite way of doing it.

Sue Nelson

And your lab is also working on bioenergy, as well?

Pamela Ronald

Yeah, so there's, of course, tremendous interest in reducing our reliance on fossil fuels. And plants produce sugars, which can be used to help develop different fuels. So that's something that we are we are interested in. There's these really amazing plants, they're perennial crops, so you don't have to plant them every year, which is nice, because you don't have to till the soil. And they're very tolerant of stress, and they grow massive. So, they have a lot of biomass. So, there's interest in trying to figure out how to cultivate these massive perennial grasses, and then collect the leaves and extract the sugars in those leaves and develop new fuels that can be used to help power the economy.

Sue Nelson

So it sounds like from your point of view, and I've seen you give talks, it's incredibly inspiring, and you can't help but be sort of motivated and sort of brought along with you, that you see the future in a very positive, helpful,

philanthropic way in that you're using, what is an amazing technological tool with genetic engineering to, I was going to say, almost feed the world save the world, but it does feel like that's what you're aiming for?

Pamela Ronald

Yeah, well, thank you. I think a lot of plant biologists are driven just for that. I mean, many of us, well, I can speak for myself, I came from I came to plant biology, because of my love for the natural world. I you know, I grew up in the summers in the mountains and then also, I think many people want to contribute to the public good and society. We only have one life, so, if we're lucky enough to work with people, like minded people to try to develop some useful tool, I think it's really important. So we need all the young people to find out what they're interested in and use that to try I think, to try to address some of the greatest challenges of today, which is to feed the growing population to reduce negative impacts on the climate and the environment. So I think that's something that, it is inspiring to work with people that that have this goal and we are doing it right so if you have many people working on this, all of us can contribute a small bit, but then those small bits add up to really making the world a better place.

Sue Nelson

And considering your background is, as you say, it's biology, it also includes botany. Did you have any idea at the start of your career that in the end, that educational background would then also include genetic engineering?

Pamela Ronald

Well, no, because you know, engineering didn't even exist when I was walking along the mountains. And, you know, I think I was very fortunate. I didn't even really think much about a career. And then I was about 14 on a backpack trip with my brothers. And I ran into people with a book and they were identifying wildflowers. And they were, I quickly understood that they were working. And so, I thought, oh, that's what I want to do, wander around the mountains and identify flowers and get paid for it. Well, of course, as you get older and gain knowledge and if you're fortunate to college with excellent teachers, that kind of will morph into something else. And I still love to walk around identify flowers, but I got very interested in genetics, and primarily because of this idea that we can develop plants that are resistant to disease, so farmers don't have to spray pesticides. So those are the things that really drew me into this field.

Sue Nelson

Professor Pamela Ronald, thank you so much for joining me on the Create the Future podcast.

Pamela Ronald

Thank you Sue, it was fun.

Sue Nelson

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