Genome editing and green genetic engineering – a future for sustainable food production?

In this interview with Prof Dr Stephan Clemens from the University of Bayreuth, we talk about the opportunities of genome editing and genetic engineering in food production. The basis of our nutrition today is bred, i.e. genetically changed, crops. In order to counteract the advancing climate change and to feed a growing world population, methods for sustainable food production will be needed in the future. In this context, genome editing with the so-called CRISPR/Cas method and green genetic engineering offer opportunities to complement classical breeding in a meaningful way. Opportunities, risks and legal hurdles must be considered in the further development of our food production.

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KUestions is a video podcast format produced by the Akademie für Neue Medien (Bildungswerk) e.V. and the University of Bayreuth for the project Ernährungsradar. Experts are interviewed on various topics in the context of nutrition and report on the current state of research. The interview was conducted by Matthias Will from the Akademie für Neue Medien (Bildungswerk) e.V. and Carolina Hoffmann as a volunteer at the Akademie für Neue Medien (Bildungswerk) e.V.

Recommended literature on the topic

Clemens S (2021). Mehr Nachhaltigkeit durch Genomeditierung: Genetische Variation gezielt erzeugen und nutzen. Biologie in unserer Zeit. 51:337–345. https://doi.org/10.11576/biuz-4821

Deutsche Akademie der Naturforscher Leopoldina – Nationale Akademie der Wissenschaften (2019). Wege zu einer wissenschaftlich begründeten, differenzierten Regulierung genomeditierter Pflanzen in der EU. https://www.leopoldina.org/publikationen/detailansicht/publication/wege-zu-einer-wissenschaftlich-begruendeten-differenzierten-regulierung-genomeditierter-pflanzen-in-der-eu-2019/

Food and Agriculture Organization of the United Nations (FAO) (2023): Gene editing and agrifood systems. https://www.fao.org/documents/card/en/c/cc3579en

Gao C (2021). Genome engineering for crop improvement and future agriculture. Cell. 184:1621–1635. https://doi.org/10.1016/j.cell.2021.01.005

English translation of the German interview transcript

Matthias Will: Dear audience, welcome to a new interview as part of the Ernährungsradar project. In this project, the University of Bayreuth and the Akademie für Neue Medien are working closely together to inform people about nutrition. I am Matthias Will from the Akademie für Neue Medien.

Carolina Hoffmann: My name is Carolina Hoffmann. I'm currently a trainee at the Akademie für Neue Medien.

Matthias Will: Almost all of us appreciate high-quality and flavourful food, but many people also care about where this food comes from and how it was produced. Genetic engineering is a difficult topic for many consumers. Many even reject it outright. But what about genetic engineering in plants? Is it dangerous? Is it an opportunity? Does it perhaps even solve many problems? This is our topic today and our interviewee is Professor Stephan Clemens from the University of Bayreuth, where he teaches plant physiology. Professor Clemens, it's great to have you with us today.

Prof Clemens: Yes, thank you very much.

Matthias Will: Professor Clemens, the term "green genetic engineering" keeps being mentioned everywhere. Can you explain what this is all about?

Prof Clemens: First of all, the term genetic engineering simply means that I take a gene, i.e. a piece of DNA, a piece of genetic information from an organism and transfer this piece, which normally contains the information for a protein, into another organism. And green in this case simply means that it is genetic engineering of plants. This is different from red genetic engineering, which is more concerned with medical applications, or white genetic engineering, which is more concerned with industrial applications. And green is just that on plants.

Carolina Hoffmann: And for you? What is green genetic engineering for you? Is it an opportunity or a risk?

Prof Clemens: Well, for me, from my point of view as a plant scientist, it's clearly an opportunity. However, when dealing with such issues, I don't think we can necessarily decide whether it is this or that, but above all we have to see how we can maximise the opportunities and avoid the risks.

Matthias Will: Many people also see great opportunities in green genetic engineering with regard to climate change. It could help to tackle climate change. How do you see this and what is the explanation for it?

Prof Clemens: Well, we really are facing huge challenges. We still have a growing world population. We no longer have the opportunity to expand the areas of land. We should actually be trying to produce food on less land in order to promote biodiversity. At the same time, if we look at the global picture, we still have growing demands for food. In other words, we can project that we will have to produce much more in 20-30 years than we do today. And genetic engineering techniques and the new breeding methods, i.e. genome editing, offer approaches to increase precisely this productivity and at the same time reduce the environmental footprint of this food production.

Carolina Hoffmann: Surveys show that the majority of respondents are against genetically modified plants in Germany. Why does genetic engineering have such a bad reputation in the plant and food sector?

Prof Clemens: I think I need to go into a little more detail and look at a few different aspects. One point is definitely that we have never really had a debate in Germany that is based on facts to any extent, I'm afraid to say. So when I give lectures on this topic, for example, I tell the students from the outset that we are now talking about a topic where a lot of fake news exists. But a second, very important point is certainly that we need attractive products and these are lacking in this area. I think a comparison with red genetic engineering is instructive here: when the method of producing human insulin in bacteria was developed, in other words a classic genetic engineering application, the majority were initially also against it. There were also safety concerns here and people didn't want it. And there were protagonists here who claimed that it was associated with risks, that it wasn't actually good for people and so on. Today, it has become a matter of course that all diabetics receive this recombinant human insulin, which is much better than what was previously isolated from pigs. And this product has shown people: Yes, genetic engineering really is useful. And we don't yet have these products in this form in the agricultural and food sector. That is certainly also a difficulty.

Matthias Will: Supporters have high hopes for the so-called gene scissors. The so-called CRISPR/Cas method has even been honoured with the Nobel Prize or the inventors have even been awarded the Nobel Prize. Can you explain how this procedure works?

Prof Clemens: Yes, the CRISPR/Cas method is fantastically simple. It is a revolutionary technology that is basically simply based on the fact that I can make a programmed cut at a specific point in the genome, i.e. in the genetic information of an organism, which is present in long threads, the DNA threads, and cut this thread at this point. And then there are the cell's own repair systems that repair this cut again. If you want to, it often happens that the gene in which the cut was made is no longer active because one or two letters are added or no longer present during the repair. Or I try to really change a few letters during the repair. The decisive difference to classical genetic engineering is that I don't have any foreign DNA in my edited organism afterwards. In this respect, it should be clearly distinguished from genetic engineering, which is based on the fact that I transfer DNA from another organism. This is not what happens in genome editing; instead, I have changed individual letters in my edited organism afterwards.

Carolina Hoffmann: And let's be honest: do fruit from plants that have been modified with the gene scissors taste the same as normal fruit?

Prof Clemens: They certainly do. I think it's worth taking a look at what genetic modifications actually are and also how many genetic modifications take place. When I breed in the classic way, I normally have two parent individuals that I cross because I want to try to transfer certain characteristics of one individual to the offspring. Millions of changes happen in the process. Nevertheless, the fruit usually still tastes the same after crossing tomatoes or, of course, the aim is often to make them taste better. If I now work with the gene scissors, I don't have millions of changes, but I have one or very few changes. This means that the probability of something tasting or behaving differently is much lower than with a normal crossing, where I change many millions of letters. Perhaps another comparison: for decades, radioactive radiation or DNA-altering chemicals have been used in breeding to create precisely more diversity from which the breeder can then select. Again, these are thousands of changes in letters, randomly distributed in the DNA, in the genome. So here, too, I have many more changes than with the gene scissors.

Matthias Will: Nevertheless, environmental organisations vehemently warn of the risks of green genetic engineering. They say that nobody knows exactly what will happen to the plant if it is genetically modified. They say that toxins or substances can be produced that may also cause allergies. What do you say to the critics?

Prof Clemens: For the reasons I have just mentioned, because we have far fewer modifications, the probability of something like this happening is much lower than with conventional breeding. In addition, it is always the case that such plants are also analysed. We bring hundreds to thousands of new crop varieties onto the market every year, all of which have of course been subjected to a wide range of tests. And we would do the same with these plants. And unfortunately, I also have to say that we have a lot of fake news and that we don't really have fact-based discussions. We have had over 25 years of very detailed safety and risk research into traditional green genetic engineering. The results of thousands of studies worldwide all come to the same conclusion: we see no particular, no additional risks. But this scientific finding never reaches the public eye, it is simply swept under the carpet.

Matthias Will: Professor Clemens, you once said in an earlier interview that naturalness is an illusion. Do you have no respect for nature?

Prof Clemens: Well, I think the opposite is the case. I deal with nature every day in my job and am fascinated by the complexity of organisms on a daily basis, marvelling every day at how cells work, how the interaction of cells works in an organism, which bodily functions enable us to perform all kinds of services in a truly outstanding and fascinating way. It's the same with plants, photosynthesis, the ability to extract nutrients from the soil. All of this really fascinates me on a daily basis. What I mean by that sentence is more that we're falling for the marketing a bit and not using the term "natural" correctly. The point is that everything we eat that comes from crops ultimately comes from plants that have properties that are not natural. Let me illustrate this with two examples. A plant normally wants to spread its offspring. This means that the seeds are normally dropped by a plant. The embryo that sits in this seed is the next generation. This is natural behaviour. Our crop plants have mutations, genetic changes, which cause them to hold on to the seeds much more strongly. This is a characteristic that is good for humans, but in the wild it would be a great disadvantage for these plants because they simply do not release their offspring. Second example, you have already mentioned the keyword toxins. Contrary to what we might think, plants do not want to be eaten. This means that a plant's natural behaviour is to produce many toxins that make anyone who nibbles on this plant feel much worse afterwards. You can see this everywhere in nature. Herbivores normally move on, a giraffe only nibbles on a tree for a short time and then moves on because the tree resists being eaten. Our crop plants no longer produce many of these toxins. They have been selected by our ancestors. Here too, they are mutants, genetic changes that have been selected in the course of domestication and breeding. So here too, our crops are unnatural, if you like. They no longer exhibit natural behaviour, but our crops have been modified in such a way that they benefit us. In this respect, the concept of naturalness in the context of food is misleading, to say the least. And that's what I meant with this sentence.

Carolina Hoffmann: Another argument put forward by critics: "Widespread use of the CRISPR/Cas method could lead to considerable legal uncertainty in future due to the large number of patent applications. Some even fear a patenting mania. Are these concerns not understandable?

Prof Clemens: Well, patents are a complicated issue, there's no question about that. The first thing I would say is that it would always be nice if these critics would also provide evidence and arguments, which I haven't seen so far. Now to patents in general: We all always feel a bit uncomfortable about patents, but I think we have to recognise them as a necessary. Patents protect those who make innovations possible and they also protect those who try to turn scientific findings into products. If they didn't have the protection of being able to earn the profit in the end, they wouldn't do it. In other words, we would fundamentally paralyse innovation if we didn't have patents. And in other areas it's quite natural. If we now develop new battery technology, which we all want, then many components of such new batteries will of course be protected by patents so that those who develop them can earn money with them for 20 years. Firstly, that's a very basic point about patents. We need them. If we now look at CRISPR/Cas, we can see that the vast majority of patents are held by academic institutions, and they have freedom to operate. And I don't know whether anyone in the scene you are quoting has ever reported, for example, that the University of Wageningen, the largest agricultural university in the Netherlands, has released its patents on the CRISPR/Cas method for non-commercial use. This can happen in many places, and there are many examples of this already happening. To cite examples from the classic field of genetic engineering, the so-called Golden Rice, which produces vitamin A in rice grains and is now being cultivated in the Philippines. There are a lot of patents involved, but an agreement has nevertheless been reached with the patent holders, in this case companies, and they have said that as long as we use this option for non-commercial cultivation, the licence fees will be waived. So, what I'm mainly trying to say is that there is a lot of room for manoeuvre. And otherwise, of course, there is also the option of adapting patent and plant variety protection. It is always a question of legislation as to exactly how I organise this. In other words, if I now try to bring these techniques into use, which science is promoting because we see this potential, then we can simultaneously ensure that the conditions for patent and plant variety protection are created in such a way that this technology is applied as widely as possible. And all I can see in terms of trends is that there will be considerably less patent protection in the coming years. Also because there are so many CRSPR/Cas variants that can be used. And if I no longer have one technology, but 20, then of course the one loses value. And colleagues who are really involved in technology development tell me that they expect these patents to lose value very quickly. What's more, they will only be valid for a certain period of time anyway. In other words, I don't see us getting into such a patenting mania at all. And as I said, we should really try to deal with this argumentatively.

Matthias Will: In a statement by the Leopoldina, many scientists are calling for a simplification of genetic engineering legislation. There are similar endeavours at EU level, so that should be a glimmer of hope for you.

Prof Clemens: Yes, that is a glimmer of hope, but we certainly still have a long way to go. So the situation is like this, when you say renowned scientists, I would like to expand on that a little. We are talking about scientific consensus here. It is the conviction of the scientific community in Germany. It's a consensus similar to the one that we have man-made climate change. It really is the prevailing scientific opinion that we need this because genetic engineering regulation will result in Europe not being able to utilise the possibilities of genome editing, i.e. CRISPR/Cas. And the EU Commission officially stated in 2021 that the existing regulation is not suitable for really developing the potential for more sustainable agriculture. The EU is already lagging behind, while most other countries around the world are already further along in adapting regulation to the state of the art. The EU Commission will submit a proposal, hopefully this year. But there will certainly still be a lot of debate and discussion about it, especially in Germany. So there is still a long way to go, but there is a glimmer of hope.

Carolina Hoffmann: You left the Green Party because you consider them to be " scientifically destructive". As a scientist, what can you do to convince not only politicians but also sceptical consumers?

Prof Clemens: Yes, for example by doing something like this. That we try to bring the issues to the public, to offer information. We try to do that in many places. It's not easy to present yourself as a scientist in the media world. We have certain handicaps, we are obliged to be scientifically honest. For example, I cannot simply say that something has no risk, because that is simply an inaccurate statement. In other words, we have to try to stick to our professional ethos on the one hand, but still seek communication on the other. We really try to present the issues, to present them in all their facets and, of course, ultimately to gain trust. However, I also believe from the experience of recent years that we cannot do it alone. We need many partners in the media who continue to work as mediators. And ultimately, we need political courage. From many conversations with politicians, I know the phrase: "We can't win anything on this issue." "You don't have to convince us, we know what's going on." But it's an issue where you lose, because there's still this scepticism among the population. And what we hope for is a little more courage to say: "No, we have to look at all this again, we have major challenges, we have to become more sustainable, we ultimately have to respond appropriately to climate change, we also have to deal with the consequences of climate change, and deal with them as well as possible." And to do that, we also need technologies like these.

Matthias Will: Professor Clemens, thank you very much for the interview.

Prof Clemens: With pleasure. Thank you.