With a growing world population comes the necessity to improve crop varieties so that they are better suited to a range of farming systems and practices, as well as being more resilient to climate change, pests and disease. But by what means can and should we achieve this change? How can we adapt to provide enough food for our increasing population? *International Innovation* explores the issue, and speaks with Peter Melchett, Policy Director of the Soil Association and Professor Ottoline Leyser, Director of the University of Cambridge Sainsbury Laboratory, who give their differing outlooks on improving crop varieties and current EU law.

**TECHNOLOGIES**

Classically, crops cultivated for agriculture have been selectively bred for characteristics that lend themselves to agricultural production. In the process of developing ‘ideal’ varieties that are more tolerant to drought, flood, frost, pests and diseases, genetic diversity is lost as a consequence of selective breeding. This has implications for crop adaptability and resistance to fluctuating biotic and abiotic stresses, and the system’s overall resilience. The question that remains of much debate is how best to increase agricultural output while improving the resilience and sustainability of the food system, with altogether less input?

While conventional, or selective, breeding is regarded by some as a more responsible method of crop improvement, others are receptive to the use of novel genetic techniques. No method is without its risks; in fact, for many techniques the dangers are far more similar than they first appear. On the flipside, the overall outcomes of using both genetic modification (GM) and non-GM methods are becoming increasingly harder, or sometimes impossible, to tell apart. In a position statement on genetic crop improvement, the Biotechnology and Biological Sciences Research Council (BBSRC) notes that “the boundaries between established GM and non-GM techniques will become increasingly blurred as techniques develop”. If this is the case, should these methods be subjected to such different risk assessments?

In recent years, an alternative technique to classic GM methods has emerged – targeted genome editing. Said to speed up the natural process of gene adaptation, this fledgling technology is able to pinpoint mutations in a crop’s genome that would have occurred naturally through conventional breeding – thereby making it less vulnerable to stressors, or able to produce higher yields, or resistant to certain herbicides. Though the potential for this technology could be huge, it is not without its shortfalls, and there is widespread belief that the technique is just another form of GM.

Politically, the situation is also far from straightforward. Under current EU legislation the use of genome editing for crop improvement is restricted under the rules for GM. While some believe this to be necessary, those that prefer to distinguish between GM and genome editing fear the new technique’s potential will be hindered under present law. The following questions have also arisen: Should the current system undergo an even more radical change so as to regulate the crop characteristics resulting from GM and non-GM methods, rather than the techniques themselves? Is such a change in the law justified?

**TO FEED 9 BILLION?**

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First and foremost, it is important to stress that the Soil Association actively campaigns against the use of genetic modification (GM)/engineering in crops, not in medicine. We do not oppose contained use of genetic engineering. With regards to agronomy, in our view, genome editing is the same as GM – we don’t make any distinction.

EUROPEAN LAW

Although there is currently much debate over the definition of GM in European legislation, my understanding from lawyers and scientists is that it is fairly clear in that it does cover genome editing. I know two companies that developed genome editing technology and looked into this, and I have not heard either of them claim that EU law is unclear or missing any information. Changing the definition would involve changing the law, which would be a very lengthy process. As it is scientifically and politically hard to justify doing this, I don’t think it will happen. For things like organic farming, for example, this means that genome editing is still prohibited in organic production under EU law.

UNIVERSAL CONCERNS

In terms of the main issues surrounding genome editing technology, they are the same as those for GM – they are neither different, new nor lesser. Genome editing alters the base sequence of the genome and can result in unpredictable consequences. Although the companies say, for example: ‘All we’ve done is remove one gene and we’ve done it very precisely – we haven’t used the traditional scatter-gun approach of most GM technology,’ they still have no idea what the consequence of removing that gene will be on a group of genes or genes in other parts of the DNA.

The technique involved in genome editing still requires the use of genes that promote the insertion of non-transgenic material. Therefore, the process is not limited to the movement of a single gene – marker genes and a promoter (usually a virus gene) are still used, as in normal GM. If it is simply a gene from a related plant, then you can do that through marker-assisted selection, without using GM.

One argument for GM and genome editing is: ‘We’re not doing anything you couldn’t do with conventional breeding’. The answer, then, is to use conventional breeding without the risks. Marker-assisted selection is a quicker process than GM in terms of getting a product to market.

A SUITABLE ALTERNATIVE

In order to protect and strengthen agricultural farming systems, I believe marker-assisted selection is a really promising crop breeding technology, delivering real progress. GM scientists are always promising great progress in the future, but marker-assisted selection is delivering a huge number of crops being used by farmers in developing countries right now.

The real challenge for agriculture, globally, is how we produce enough food for 9 billion people while cutting greenhouse gas emissions by about 80 per cent, and ensuring people are eating a healthy diet. At the moment there is enough food for everyone, but we will require more to feed future populations. We need to do that in an environmentally friendly way, which means without manufactured nitrogen fertiliser, for example, and far less use of mineral phosphate.

The key to this is changing what people eat. In future, people will have to decide what diets under any system of farming – no system can produce a North American or even a European diet for 9 billion people. This means a lot less white meat and less dairy. Doing so will free up enough grains and pulses to feed people a healthy diet while reducing greenhouse gas emissions.

Policy Director for the Soil Association, Peter Melchett, offers his perspective on the distinction or lack thereof between genome editing and genetic modification, and why he believes marker-assisted selection techniques are the way forward.
Improving crop varieties is one of a raft of measures that can help boost the sustainability and security of our food supply chain. Because of the importance of these objectives, it is necessary to take advantage of all the options available, from reducing post-harvest waste to improved agronomic practices. Within this range, improving crop varieties has a significant part to play.

The characteristics of any crop variety are determined by its genetic makeup and the way in which the plant interacts with the environment in which it grows. Many of the characteristics that we value in agriculture do not occur in nature. For example, wild plants that produce large, soft seeds that remain on the plant would not thrive as the seeds would easily be eaten by animals, and those that weren’t would be very poorly dispersed. However, these are both extremely important characteristics for many cereal crops. Because of this, since the dawn of agriculture thousands of years ago, we have selected and bred plant varieties to improve their characteristics as crops. Many of our staple crops are therefore highly tuned for agricultural production but also lack genetic diversity, which has been lost during the breeding process.

IMPROVING GENETIC DIVERSITY

There are many methods available to introduce genetic diversity into these elite crop lines. These include: crossing different varieties together, crossing a crop with genetically diverse wild relatives, treating a crop with chemicals or radiation to induce random genetic changes, adding individual new genes or targeting changes to existing genes. Until recently, the main approach was to cross together different crop varieties or a crop variety with a wild relative – thereby mixing together their genes – and then selecting out plants derived from those crosses that had the desired combination of characteristics. This can be very slow as it can take many generations to bring the right combinations of genes together in a single variety. The process has recently been sped up due to a better understanding of which genes should be selected, allowing them to be identified and traced through the breeding process, making it easier to pick out the desired varieties. This is called marker-assisted breeding.

At present, there is a lot of interest in genetic modification (GM) and genome editing approaches. An important advantage of these approaches is that they allow very small genetic changes to be made in elite crop varieties, avoiding the problems encountered by mixing genes together, which is essential to conventional breeding. GM involves adding one of a small number of genes to a crop variety. Genome editing can be used in the same way, except that the position in the crop’s DNA where the new gene is added can be selected. In addition, genome editing can be used to make changes to the genes already in a crop variety. These methods are of value in a limited range of situations, when we know exactly which versions of which genes can produce the characteristic of interest in a crop.

For example, these techniques might be particularly useful in the endless arms race against crop diseases. To protect crops from diseases it is possible to use chemical pesticides, but as these are often damaging to the environment, genetic resistance is preferable. However, the organisms that cause the diseases can evolve to overcome these genetic resistance mechanisms, so it is a constant battle for plant breeders to find new resistance genes to breed into crops. We now know a huge amount about these disease resistance genes, and so it is possible to introduce them using GM. With the new genome editing techniques, in some cases it may be possible to edit a crop’s existing disease resistance genes to keep one step ahead of the pathogen.

RISK ASSESSMENT

Each of the above techniques to introduce genetic diversity has advantages and disadvantages. After extensive investigation there is no evidence that any of the techniques themselves pose inherent risks. In all cases, however, there is the possibility that along with the intended genetic changes, there will be unintended ones. These risks are typically higher for conventional breeding approaches, where crossing together different varieties will result in many genetic differences in the new variety.
There has been extensive discussion about the risks of GM, but the concerns of even its most staunch critics either apply at least as strongly to conventional breeding, as in the case of unintended genetic changes, or they relate to the new characteristic that has been introduced into the crop. The latter is an extremely important consideration. A crop with a new characteristic may well have impacts on the agroecosystem as well as the food chain.

I think it is entirely reasonable that when a new crop characteristic is brought into agriculture, there is careful consideration of the risks and benefits associated with it. However, it is the new characteristic that is relevant here, not the method by which it is introduced.

A NEED FOR CHANGE
Let’s consider herbicide resistance. It is one of the main applications for GM currently in use around the world and it has been hugely controversial. Herbicide tolerant crop varieties are also produced by conventional breeding, and raise exactly the same issues as GM herbicide tolerant varieties; however, in most countries they are not subject to the same risk assessments because legislation is focused on the method by which new characteristics are introduced, and not on the characteristics themselves. In my opinion, this methods-based approach does not provide the best safeguards for the sustainability, security and safety of the food supply chain.

Another major problem with this approach is that it is very inflexible and cannot easily adapt to new technologies as they arise. In this context, genome editing provides a case in point. There is currently an ongoing debate about whether or not genome editing is GM under the current regulations. The fact that this has become an important question illustrates how flawed the current system is. The outcome of conventional breeding, marker-assisted breeding, mutational breeding, GM and genome editing is, in all cases, new crop varieties with unique genetic characteristics. Risk assessment should focus on these unique genetic characteristics, not the method by which they were introduced. We need to move as quickly as possible towards a universal and robust system based not on method, but on the novel characteristics of a new crop variety.

Unfortunately, the issue is so politically charged that these changes are likely to take a long time to deliver because they will likely be described as relaxing the rules on GM crops. In reality, they would rather strengthen the system by extending proportional risk-based assessments to all new crops.