How ‘speed breeding’ will help expand crop diversity to feed 10 billion people

With an ever-increasing human population, predicted to be 10 billion people by 2050, studies estimate that we need to double the rate of genetic gain in our crop improvement programs globally to meet this demand. Dr Lee Hickey is a plant breeder and crop geneticist. He and his team are seeking to develop plant breeding tools that could help to enable this genetic gain.

When one considers the other challenges of increased climatic fluctuations, more drought, more heat, and evolving pathogens; we begin to understand the challenges to food security we are facing globally. Without a doubt, improving the genetics of crop varieties needs to be done in parallel with improving farming practices to deliver more efficient food production systems.

In recent years, we’ve had a massive boom in terms of genomics. The advances in the technology for genotyping have been huge. We’re now able to genotype plants, at will, and at very low costs; and get sequence information or high-density DNA markers across the genome at very low costs. This has revolutionized plant breeding, for instance enabling plant breeders to track genes and even develop predictive breeding approaches such as genomic selection. All of this has transformed the science of plant breeding and has huge potential for crop improvement.

However, one of the key limitations in the development of an improved crop variety is actually how long it takes to grow a plant generation. At the moment, using traditional approaches, it will take more than a decade from making the critical cross to releasing the improved variety.

We need to develop more robust and productive crops faster than traditional approaches allow. The challenges we are facing call for an integration of technologies to enable us to develop crops faster than ever before. Speed breeding is all about growing plants quickly, efficiently and as cheaply as possible. Through speed breeding technology, we are trying to revolutionize how we grow plants to keep pace with the advances in genomic technology in recent years.

Image not found or type unknown

wheat weaving twisted grain like
Image: Deposit Photos

Speed breeding any species

While speed breeding technology was originally developed and applied to wheat many years ago, more recently, we have adapted the approach to a range of important crops. We have published protocols that enable rapid cycling of other long-day and day-neutral crops like barley, canola, and chickpea. It has been a pleasure to collaborate with the John Innes Centre to assemble the data, information, and details needed to speed breed whatever crop researchers or breeders would like to grow around the world and make protocols for speed breeding available globally.

There has been a limitation to speed breeding short-day crops, because of their requirements for flowering. However, most recently, we have been working with International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), as part of a Bill and Melinda Gates Foundation project, to develop protocols suitable for short-day crops like sorghum, millet and pigeon pea. I believe that we can speed-breed any species. It is just a matter of optimizing the protocol and the conditions that are required for inducing early flowering and achieving rapid generation advance.

Sorghum, millet and pigeon pea are important crops for many smallholder farmers in Africa and Asia, so it's been really exciting, optimizing protocols for these crops. As part of that project, we're developing speed-breeding facilities in Asia and Africa to facilitate speed breeding crops for the future to regions of the world that need it the most.

Harnessing speed breeding techniques for crop improvement

We've got to stop thinking about breeding technologies in isolation. Our current research is focused on combining speed breeding protocols with other technologies and integrating them together. We are working on a couple of areas, with various companies and partners around the world, to make great leaps in plant breeding.

Combining speed breeding with genome editing and transgenic pipelines

Transgene and genome editing are really exciting biotechnologies – essentially plant scientists now can edit any gene they want to, at will, using very refined and targeted systems in the lab. However, plant breeding technologies have to be scalable. There are a lot of bottlenecks in the genome editing and transgenic pipelines which prevent scaling developments up and delivering improved crop varieties to people globally.

The lab actually holds us back when it comes to plant breeding. Anything that goes to the lab is a bottleneck – for example, the lengthy passages through tissue culture systems. It can take nine months from particle bombardment to producing seed from those transformed plants. Often the whole process is limited to just one or two specific genotypes that are very favored for the tissue culture regeneration process.

At The University of Queensland, we're developing a system called Express Edit, which aims to take genome editing, out of the lab, to avoid bottlenecks and improve scalability. We want to make a very flexible tool that can be used on any genotype and avoid the whole tissue culture process. Our idea is to do this directly within the speed breeding process. If we can achieve this, it will be a flexible breeding tool that will transform plant breeding. It would mean that we can achieve up to six generations a year with genome editing incorporated into the whole breeding process.

.

Combining genomic selection with speed breeding

I think genomic selection is the perfect match for speed breeding as genomic selection serves to reduce the breeding timeframe by removing the need to actually do the field testing to identify parents that can be used for the next cycle of breeding. This is done through algorithms that use sequence information, or DNA markers, to predict the performance of those plants.

If you can accurately predict performance of a plant for any trait, like yield or quality, or disease, you don’t need to go to the field for evaluations. This means that in a sense, speed breeding can become “detached” from the field testing operations and the predictive breeding cycles can go very, very fast. Of course, there’s still a need to develop lines that are genetically stable through inbreeding and these must go into field trials as normal, but your actual engine room for genetic gain can go much, much faster, and this is a really exciting space to be experimenting with.

We are very fortunate to be working with a breeding company in Australia which means we have access to massive datasets – we’re talking training datasets comprising 700-yield trials and more than 50,000 breeding lines, fully genotyped. We’re developing a totally new methodology where we combine speed breeding and genomic selection and we’re calling it ‘speed GS’.

However, we’re not just doing the standard genomic selection. We’re taking it one step further. Collaborators at The University of Queensland, including Dr Kai Voss-Fels and one of the co-inventors of genomic selection, Professor Ben Hayes, are injecting some very innovative concepts into this project. We’re using a branch of artificial intelligence to not only predict the best performance based on genotyping, but also predicting which are the best parents to use for crossing.

So far, our preliminary results indicate that huge genetic gain can be achieved through this approach. If we can get this working and demonstrate that this actually delivers crops that are capable of dramatic increases in yield, then I believe we will have the tools that we need to develop the crops to feed the world into the future.

Collaboration is key

Through our collaborative research and partnerships, if we can demonstrate that integrating these technologies can lead to more efficient systems, I think they could be game changers in the world of plant breeding. This is what science should be all about: collaboration and sharing and making this information available. We achieve things so much faster by working together.

I'm going to be giving an overview of the development of speed breeding protocols so far and share the latest unpublished protocols at the upcoming Plant Genomics & Gene Editing Congress. I'll also be sharing the latest on our effort to develop the Express Edit approach and artificial intelligence-driven speed breeding approaches. I'm looking forward to presenting these new ideas and collaborating with others to develop the crops we need for food sustainability, fast enough.

Dr Lee Hickey is a plant breeder and crop geneticist within the Queensland Alliance for Agriculture & FoodInnovation at The University of Queensland, Australia.

This article was originally published on the Global Engage blog. The article was guest authored by Nigel Halford in a series for the 8th Plant Genomics & Gene Editing Congress: Europe. Follow Global Engage on Twitter @Agbio_GE and visit their LinkedIn page