# GRDsC PODCAST TRANSCRIPT

**Plant breeding and genetics: Understanding the basics**

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**Intro:** This is a GRDC podcast.

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**Dr Greg Rebetzke:** I'm so thrilled to be part of an industry that's so active and so engaged in picking up and supporting new technologies that will benefit in the short and longer term, and particularly with this uncertainty around climates, uncertainty around fuel and fertiliser costs, we're all doing our best to support growers through new research, but also through the development release of new competitive crop varieties.

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**Sally Maguire:** That's Dr Greg Rebetzke, chief research scientist at CSIRO Agriculture and Food, and I'm Sally McGuire. Today we're delving into a practice that's almost as old as human civilisation and is still reaping benefits for the growers of today and hopefully tomorrow as well. So, it's back to Dr Rebetzke for a little history lesson on plant breeding.

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**Dr Greg Rebetzke:** Well, it went back a long time, in fact, as far back as 10,000 years ago, with the development of agriculture and nomadic people building around villages and the need to sustain themselves for food. And so, the early breeders, estimated around 7-8000 years ago, we were identifying that certain wild plants perform better for various reasons. High yielding, they maintained their grain, they were more productive, were retained, and from that these were then used to plant crops across a range of species, but particularly out the Fertile Crescent through the Middle East with our cereals. So that was probably the very earliest evidence of plant breeding. But scientific breeding probably didn't start until Mendel, back in the mid-1800s, with his development of the laws of inheritance. And so, what Mendel did was effectively identified the basis of genetics and that was the gene, without actually knowing the gene. And he did that through maths and good observation around field peas, so that was mid-1800s. And then Johansson, a Danish scientist using statistics and based on Mendel's learnings, was then able to identify that a breeding line better predicted its progeny in terms of its appearance than the original mother. And so, from that we had the development of what we call pure line theory, which became the basis of commercial breeding. It was around comfort that what you saw as a phenotype in some ways was repeatable, was carried through. So scientific breeding really around Mendel's and Johansson's identification of the science. And then I think from around the 1930s, you then had commercial maize breeding in the US, you had animal breeding, which really ramped up the need for greater rigour in terms of the statistics, the genetics and the breeding methodology, because now we were moving from research to commercialisation and competition in the marketplace. And so, I guess the science that built and was formed around that commercialisation really, really drove a real upskilling and I guess a stronger cost effectiveness to develop and deliver commercial varieties in a way that was not prohibitive. And so breeding companies have since been very, very active in picking up new genetic methods, new phenotyping methods, new statistical methods, and testing methods that would increase the quality of the varieties being developed for lower cost, and that way, maintaining active breeding programs in a way that are highly competitive in the marketplace. So that's pretty much the history of plant breeding. And I guess for me, that history is continuing because we're learning more and more around the genetics and the capacity to engage science in a way that's becoming a little more focused and targeted around the genes that are going to provide growers with enduring profitability into the future.

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**Sally Maguire:** Give me a bit of an overview, then, of the work that you do now as part of CSIRO.

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**Dr Greg Rebetzke:** So I'm called a pre-breeder. I actually don't develop commercial varieties. My science and the science of my colleagues here at CSIRO, but also across the public sector and some private breeding companies really are focusing around the traits, the genetics and the methodologies that will improve the capture and uptake in new varieties released by commercial breeding companies. We also have a training role. And so the genetics that I work in are genetics that I've identified in regular communication with growers and with industry, the breeding industry as well. And then my role is to identify where there's some need for fine proofing the traits, maybe around improved coleoptile for deep sowing, it might be around improved frost tolerance, it may be around improved weed competitiveness. And if those genetics are not well demonstrated or not well placed in commercial breeding companies, my work is to try and understand why that is. And then if there is a need, then how can we provide the genetics and the tools to improve the capture and uptake in the breeding of new commercial varieties with those new genetics?

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**Sally Maguire:** How do you actually go about finding the traits that you want in varieties?

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**Dr Greg Rebetzke:** It's actually the growers. For many years I would go to conferences and listen to other pre-breeders, but it really came about from going to field days, looking at reports that identify where the issues are, where limitations are in profitability, and I guess productivity. And so, the traits I've targeted are traits which are novel in terms of their frequency in commercial breeding companies. There's no point doing what breeders do. There's no point repeating what breeders do because breeders do it much more cost effectively. They've got incredible capacity around genetic technologies and phenotyping phenomics statistics. So I've got to try and find where the opportunity lies to support the growers through new characteristics. And so, it's talking regularly with growers, it's listening at grower updates and having my phone on 24/7 where I am available to listen to and understand what the issues are with growers around resilience in their farming system. The other place I've found quite useful has been social media. Growers are fantastic in Twitter and Facebook identifying where they've been issues, and so it's just keeping an eye open to where there may be a need to provide support, then following up with specific growers or agronomists to understand what this is an issue, and where I and other pre-breeders may be able to provide some support.

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**Sally Maguire:** Getting down to the nuts and bolts of it, how do the genetics all sort of work together, fit together? Can you just keep adding more in?

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**Dr Greg Rebetzke:** Genetics that underpin a commercial variety range from very simple genetics, and that effectively means that it's fairly simple to target and select, and that's fairly typical of some quality, some soil constraint like acidity and some disease traits. But then a large mainstay of commercial breeding is around complex genetics. So these are traits like yield which are controlled by many, many genes. And so the challenge for a breeding company is to use statistics, use biotechnology, use speed breeding, and use high throughput phenotyping in a way that those tools can be optimised over the stages of selection from a cross of two parents in developing populations, and then how those different tools can be managed to deliver reliably a new set or new package of genes that represent the very best disease resistance, the very best grain yield, the very best grain quality, and the very best adaptation across a wide range of potential climate scenarios and farming systems in a way that their variety is at a commercial head over other commercial varieties in the marketplace. And I guess we have a range of private breeding companies that represent the different commodities in Australia, from wheat to barley to canola to sorghum. And it's that competition, and it's the technology and how that technology is used by those individual breeding companies that really drives the success and adoption of a commercial variety. And I guess the growers are very lucky in Australia that we have this system of competition, which means that the very best genetics and the very best implementation of breeding methods are delivered to give growers options across a wide range of varieties and testing of those varieties for their farms. So the methodology for breeding hasn't changed radically over the past 50 to 100 years. It's been the tools that the GRDC have invested in, the breeding companies, and the pre-breeding organisations have invested in that have really allowed breeders to capture in a very cost effective and time effective way, how they can really drive existing conventional breeding methods. And I guess for me, we're moving into a realm now where we've understood from what the plant looks like, the phenotype as to what the underlying genetics look like and may be selected for. As we move into more complex traits, we're using statistics and potential methods like gene editing to really target more effectively those key genes, which are really going to drive improved productivity and improve resilience into future varieties for future climates.

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**Sally Maguire:** If we look at something like the frost tolerance gene or indeed the drought tolerant gene, why is it so hard to find that and to isolate it?

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**Dr Greg Rebetzke:** Good question. There’re two factors there. Sometimes we don't have the genetics in our crop that will allow us to resist a significant climate event, like frost, or extreme drought or extreme heat. It doesn't mean we can't move towards improving productivity with those environmental challenges. It's just that in the case of drought, crops need water. And so rather than focusing on resistance to drought, Australian breeders are very, very effective at improving water productivity. So increasing the yield per unit of water used is a much more reasonable goal than drought resistance per se, because we know that in breeding for drought resistance, we often also focus on very dry years, and there's often a trade off in wetter years. So water productivity for drought has become a focus, and I think Australian breeders have done an amazing job in continuing performance with breeding around improved water productivity for our rain fed systems. Frosts tolerance is a challenge because unlike barley and oats, we don't have a lot of the genetics that will give us this ability to survive the ravages of frost. And there our goal is not to improve frost resistant varieties, but to reduce the frost damage. And so, in the case of a significant frost event, are we able to reduce the impact of the frost, understanding that, like with drought, that we will still reduce some yield, but let's perhaps reduce the damage so that growers are able to sustain some yield. And there's some characteristics that we are learning about from a pre-breeding perspective. There's some very novel research around the importance of ice nucleating bacteria. So there are sort of other opportunities which will allow us to reduce the very negative effects of some of these extremes in climate going forward. With frost and drought too, there may be other options. And so the idea of the capacity for grazing of frost or heat damaged or drought damaged crop, or perhaps cutting it for hay, may provide growers in more extreme situations to provide them with alternative uses of climate damaged crops. But by and large, our focus should be on milling yield. And so, efforts towards improving water productivity, reducing frost and heat damage will be ongoing activities in the pre-breeding and breeding space going forward. The science in breeding is identifying and assembling sometimes thousands of genes that improve yield and quality while maintaining or capturing new genes for improved disease resistance, optimal flowering date, herbicide, acid soil tolerance, and other traits that may be more specific to individual crops. The list goes on and on and on. But the important thing is when we're talking about new varieties, we're talking about many different traits and many different genes that are required to ensure that the varieties, the breeders release and develop are capturing the best fit for a farming system and the greatest return at reduced cost. Now, some traits are controlled by single genes. So these are genes that have large effect and these genes that control traits like flowering time, plant height, whereas other traits are much more genetically complex. And what that means is that those traits contain many genes of small effect. And so these are much more challenging to manipulate. So when we talk about having complex traits and we're breeding for these, and there's sometimes many different traits controlled by many different genes, suddenly breeding goes from an art to being much more scientific. Unfortunately, mathematics dictates for a breeder how many genes can be manipulated at any one time. So over the past 20-30 years, new breeding and statistical tools have been developed to help breeders manage these large numbers of genes. We often talk in breeding of a numbers game. How many, hundreds or thousands of genes can a breeder or breeding program manage? But there's a limitation on how many genes, just statistically, how many genes can be manipulated at any one time in this numbers game and particularly using traditional breeding methods. And then the other issue that breeders have to grapple with is as new traits are introduced into a program, it often introduces new genes, and sometimes these new genes can come with them a small cost or a trade-off under some conditions. So breeders have to recognise and manage these trade-offs and when and where they exist. So modern breeding relies on genetic and statistical tools that allow for new genes to be introduced, identified while managing all the other important characteristics growers and our markets demand of our Australian crop varieties. It's quite challenging. And for that reason, people often view breeding as being quite slow.

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**Sally Maguire:** Can you give us a bit of detail around how GRDC invests in and works with CSIRO on plant breeding programs, and maybe just tell us specifically about some current investments.

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**Dr Greg Rebetzke:** The GRDC have significant investment provided by the growers and also through levies, through taxpayers, and then leverage that against organisations like CSIRO in a co-investment manner so growers get significant value for their levy. And when an idea is raised by GRDC, or even by CSIRO, or another pre breeding agency, it's then assessed, and the value of that trait is then determined in an economic way. This is something that the GRDC should invest in. And sometimes that investment is very close to market, sometimes that investment is much longer term. And so factors around we call the value proposition and the likelihood of success are considered when an investment is made. Investments which are less regular, I guess, so long coleoptile is something that has become incredibly important recently, and it will continue investing, as will frost, some areas I'm involved in. But then you have investments such as the disease investment. So the work with CSIRO, CCDM and others around rust, sclerotinia, those are ongoing investments which are key to reducing the risk of a crop failure, and also to increase the profitability by reducing the need for fungicide. So GRDC looks at where the issues may be and then invest appropriately to ensure that growers get good bang for buck, good value for dollar, but also to ensure that growers can enjoy enduring profitability. I've only spoken about a few of the investments. There are many, many other investments around the genetics. But GRDC also invest in statistics, they invest in AI, they invest in NVT, they invest in new phenotyping methods, so phenomics, they invest in digital agriculture. All of these have some impact and some place in the development, adoption of a new commercial variety. As I've indicated, it's really about the tools that will help breeders develop the next perfect variety for a grower. And I guess GRDC is incredible in providing that support. I think it's almost a bit of an envy of many other parts of the world, where other research agencies may not have quite the same support from their growers in terms of investing in short and long-term research. I think the other powerful component to all this is all this work is underpinned by quality science, and we need to ensure continued investment in capacity building and so the scientists of our future will be absolutely instrumental in us passing on the baton in the science that underpins the development and delivery of new commercial varieties. And so, again, GRDC and the breeding companies very much in support of this clear importance in capacity building. Who are the scientists and the breeders of our future is absolutely critical as well.

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**Sally Maguire:** That was Dr Greg Rebetzke, chief research scientist at CSIRO Agriculture and Food, talking about the worlds of pre-breeding, plant breeding and plant genetics. More information on these topics can be found in the description box below or online at grdc.com.au. I'm Sally Maguire. This has been a GRDC podcast. Thanks for listening.