

Crop shortages

A lack of breeders to apply the knowledge from plant science is jeopardizing public breeding programmes and the training of future plant scientists

Howard Wolinsky

In the midst of an economic downturn, many college and university students in the USA face an uncertain future. There is one crop of graduates, though, who need not worry about unemployment: plant breeders. “Our students start with six-digit salaries once they leave and they have three or four offers. We have people coming to molecular biology and they can’t find jobs. People coming to plant breeding, they have as many jobs as they want,” said Edward Buckler, a geneticist with the US Department of Agriculture’s Agricultural Research Service Institute for Genomic Diversity at Cornell University (Ithaca, NY, USA).

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The secret behind the success of qualified breeders on the job market is that they can join ‘Big Ag’—big agriculture—that is, major seed companies. Roger Boerma, coordinator of academic research for the Center for Applied Genetic Technologies at the University of Georgia (Athens, GA, USA), said that most of his graduate and postdoctoral students find jobs at companies such as Pioneer, Monsanto and Syngenta, rather than working in the orchards and fields of academic research. According to Todd Wehner, a professor and cucurbit breeder at the Department of Horticultural Science, North Carolina State University (Raleigh, NC, USA), the best-paying jobs—US\$100,000 plus good

benefits and research conditions—are at seed companies that deal with the main crops (Guner & Wehner, 2003). By contrast, university positions typically start at US\$75,000 and tenure track.

As a result, Wehner said, public crop breeding in the USA has begun to disappear. “To be clear, there is no shortage of plant breeders,” he said. “There is a shortage of plant breeders in the public sector.” The lure of Big Ag depletes universities and research institutes of plant breeders—who, after all, are the ones who create new plant varieties for agriculture—and jeopardizes the training of future generations of plant scientists and breeders. Moreover, there is an increasing demand for breeders to address the challenge of creating environmentally sustainable ways to grow more food for an increasing human population on Earth.

At the same time, basic plant research is making rapid progress. The genomes of most of the main crop plants and many vegetables have been sequenced, which has enabled researchers to better understand the molecular details of how plants fend off pests and pathogens, or withstand drought and flooding. This research has also generated molecular markers—short regions of DNA that are linked to, for example, better resistance to fungi or other pathogens. So-called marker-assisted breeding based on this information is now able to create new plant varieties more effectively than would be possible with the classical strategy of crossing, selection and backcrossing.

However, applying the genomic knowledge requires both breeders and plant scientists with a better understanding of each other’s expertise. As David Baulcombe,

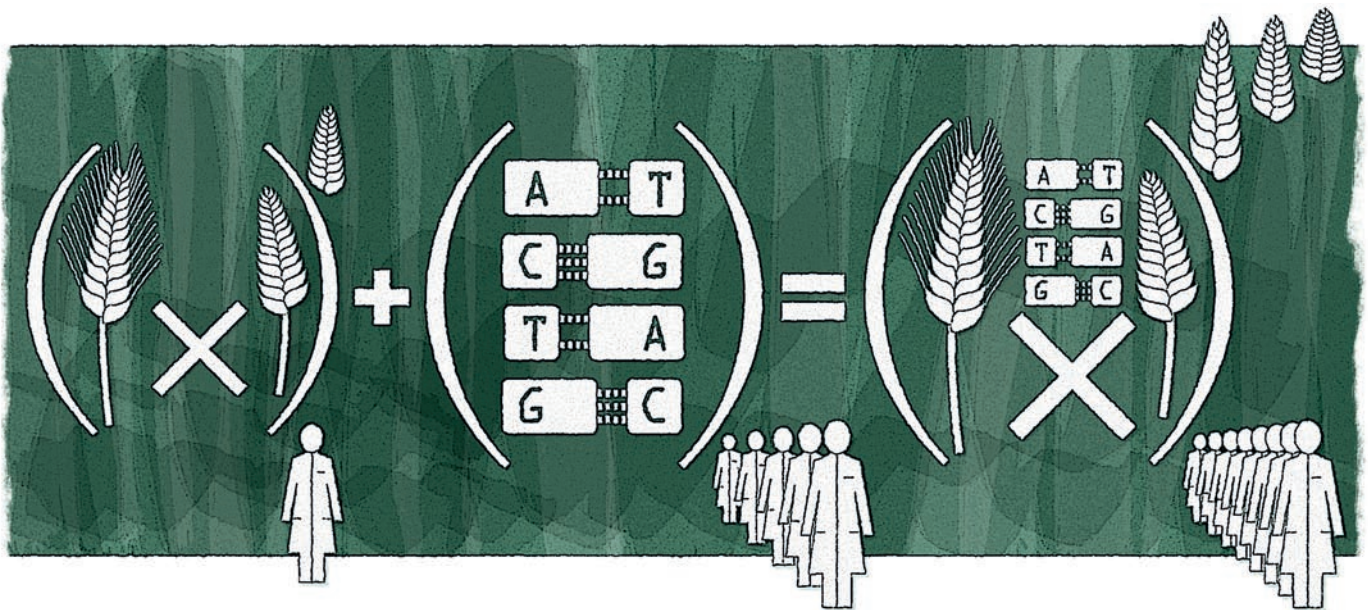
professor of botany at the University of Cambridge, UK, commented, “I think the important gap is actually in making sure that the fundamental scientists working on genomics understand breeding, and equally that those people doing breeding understand the potential of genomics. This is part of the translational gap. There’s incomplete understanding on both sides.”

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In the genomic age, plant breeding has an image problem: like other hands-on agricultural work, it is dirty and unglamorous. “A research project in agriculture in the twenty-first century resembles agriculture for farmers in the eighteenth century,” Wehner said. “Harvesting in the fields in the summer might be considered one of the worst jobs, but not to me. I’m harvesting cucumbers just like everybody else. I don’t mind working at 105 degrees, with 95% humidity and insects biting my ankles. I actually like that. I like that better than office work.”

For most students, however, genomics is the more appealing option as a cutting-edge and glamorous research field. “The exciting photographs that you always see are people holding up glass test tubes and working in front of big computer screens,” Wehner explained.

In addition, Wehner said that federal and state governments have given greater priority and funding to molecular genetics



than to plant breeding. “The reason we’ve gone away from plant breeding of course is that faculty can get competitive grants for large amounts of money to do things that are more in the area of molecular genetics,” he explained. “Plant breeders have switched over to molecular genetics because they can get money there and they can’t get money in plant breeding.”

“The frontiers of science shifted from agriculture to genetics, especially the genetics of corn, wheat and rice,” agreed Richard Flavell, former Director of the John Innes Centre (Norwich, UK) and now Chief Scientific Officer of Ceres (Thousand Oaks, CA, USA). “As university departments have chased their money, chased the bright students, they have [focused on] programmes that pull in research dollars on the frontiers, and plant breeding has been left behind as something of a Cinderella subject.”

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In a sense, public plant breeding has become a victim of its own success. Wehner explained that over the past century, the protection of intellectual property has created a profitable market for private corporations to the detriment of public programmes. “It started out where they could

protect seed-propagated crops,” he said. “The companies began to hire plant breeders and develop their own varieties. And that started the whole agricultural business, which is now huge.”

As a result, Wehner said, the private sector can now outmanoeuvre public breeders at will. “[Seed companies] have huge teams that can go much faster than I can go. They have winter nurseries and big greenhouses and lots of pathologists and molecular geneticists and they have large databases and seed technologists and sales reps and catalogue artists and all those things. They can do much faster cucumber breeding than I can. They can beat me in any area that they choose to focus on.”

He said that seed corporations turn only to public breeders when they are looking for rare seeds obtained on expeditions around the world or special knowledge. These crops and the breeders and other scientists who work on them receive far less financial support from government than do the more profitable crops, such as corn and soybean. In effect, these crops are in an analogous position to orphan drugs that receive little attention because the patients who need them represent a small economic market.

The dwindling support for public breeding programmes is also a result of larger political developments. Since the 1980s, when British Prime Minister Margaret Thatcher and US President Ronald

Regan championed the private sector in all things, government has consistently withdrawn support for public research programmes wherever the private sector can profit. “Plant breeding programmes are expensive. My programme costs about US\$500,000 a year to run for my crops, watermelon and cucumber. Universities don’t want to spend that money if they don’t have to, especially if it’s already being done by the private sector,” Wehner said.

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“Over the last 30 years or so, food supplies and food security have fallen off the agenda of policymakers,” Baulcombe explained. “Applied research in academic institutions is disappearing, and so the opportunities for linking the achievements of basic research with applications, at least in the public sector, are disappearing. You’ve got these two areas of the work going in opposite directions.”

There’s another problem for plant breeding in the publish-or-perish world of academia. According to Ian Graham, Director of the Centre for Novel Agricultural Products at York University in the UK, potential academics in the plant sciences are turned off by plant breeding as a discipline

because it is difficult to publish the research in high-impact journals.

Graham, who is funded by the Bill & Melinda Gates Foundation to breed new varieties of *Artemisia*—the plant that produces the anti-malarial compound artemisinin—said this could change. “Now with the new [genomic] technologies, the whole subject of plant breeding has come back into the limelight. We can start thinking seriously about not just the conventional crops [...] but all the marginal crops as well that we can really start employing these technologies on and doing exciting science and linking phenotypes to genes and phenotypes to the underlying biology,” he said. “It takes us back again closer to the science. That will bring more people into plant breeding.”

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Buckler, who specializes in functional genomic approaches to dissect complex traits in maize, wheat and *Arabidopsis*, said that public breeding still moves at a slower pace. “The seed companies are trying to figure out how to move genomics from gene discovery all the way to the breeding side. And it’s moving forward,” he said. “There have been some real intellectual questions that people are trying to overcome as to how fast to integrate genomics. I think it’s starting to occur also with a lot of the public breeders. A lot of it has been that the cost of genotyping, especially for specialty crops, was too high to develop marker systems that would really accelerate breeding.”

Things might be about to change on the cost side as well. Buckler said that decreasing costs for sequencing and genotyping will give public breeding a boost. Using today’s genomic tools, researchers and plant breeders could match the achievements of the last century in maize breeding within three years. He said that comparable gains could be made in specialty crops, the *forte* of public breeding. “Right now, most of the simulations suggest that we can accelerate it about threefold,” Buckler said. “Maybe as our knowledge increases, maybe we can approach a 15-fold rate increase.”

Indeed, the increasing knowledge from basic research could well contribute to significant advances in the coming years. “We’ve messed around with genes in a rather blind, sort of non-predictive process,” said Scott Jackson, a plant genomics expert at Purdue University (West Lafayette, IN, USA), who headed the team that decoded the soybean genome (Schmutz *et al*, 2010). “Having a full genome sequence, having all the genes underlying all the traits in whatever plant organism you’re looking at, makes it less blind. You can determine which genes affect the trait and it has the potential to make it a more predictive process where you can take specific genes in combinations and you can predict what the outcome might be. I think that’s where the real revolution in plant breeding is going to come.”

Nevertheless, the main problem that could hold back this revolution is a lack of trained people in academia and the private sector. Ted Crosbie, Head of Plant Breeding at Monsanto (St Louis, MO, USA), commented at the national Plant Breeding Coordinating Committee meeting in 2008 that “[w]e, in the plant breeding industry, face a number of challenges. More plant breeders are reaching retirement age at a time when the need for plant breeders has never been greater [...] We need to renew our nation’s capacity for plant breeding.”

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Dry bean breeder James Kelly, a professor of crop and soil sciences at Michigan State University (East Lansing, MI, USA), said while there has been a disconnect between public breeders and genomics researchers, new federal grants are designed to increase collaboration.

In the meantime, developing countries such as India and China have been filling the gap. “China is putting a huge amount of effort into agriculture. They actually know the importance of food. They have plant breeders all over the place,” Wehner said. “The US is starting to fall behind. And now, agricultural companies are looking around wondering—where are we going to get our plant breeders?”

To address the problem, major agriculture companies have begun to fund fellowships to train new plant breeders. Thus far, Buckler said, these efforts have had only a small impact. He noted that 500 new PhDs a year are needed just in maize breeding. “It’s not uncommon for the big companies like Monsanto, Pioneer and Syngenta to spend money on training, on endowing chairs at universities,” Flavell said. “It’s good PR, but they’re serious about the need for breeders.”

The US government has also taken some measures to alleviate the problem. Congress decided to establish the US National Institute of Food and Agriculture (Washington, DC, USA) under the auspices of the US Department of Agriculture to make more efficient use of research money, advance the application of plant science and attract new students to plant breeding (see the interview with Roger Beachy in this issue, pp504–507). Another approach is to use distance education to train breeders, such as technicians who want to advance their careers, in certificate programmes rather than master’s or doctorate programmes.

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“If [breeding] is not done in universities in the public sector, where is it done?” Flavell asked about the future of public breeding. “I can wax lyrical and perhaps be perceived as being over the top, but if we’re going to manage this planet on getting more food out of less land, this has to be almost one of the highest things that has got to be taken care of by government.” Wehner added, “The public in the developed world thinks food magically appears in grocery stores. There is no civilization without agriculture. Without plant breeders to work on improving our crops, civilization is at risk.”

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