

PART 3

MODERN PLANT BREEDING

Gregor Mendel's discovery of the rules of heredity in the mid-19th century is a convenient marker for the beginning of modern plant breeding. The ability of scientists to envision an improved version of a crop plant, then forge their vision into reality has thoroughly transformed the world. Crop yields have increased multi-fold, resistance to many pests and diseases has reduced losses significantly, and as readers will see in Chapter 13, crop tolerance to severe stresses promises to change the lives of some of the world's most marginalised farmers.

The origin of modern plant breeding is largely one of public sector investments. Two key vehicles for this were establishment of the US Department of Agriculture and the US Land Grant University system initiated in the early 1860s – about the time Mendel was wrapping up his studies on inheritance. Clearly stated within their mandates were the development of improved crops and cropping practices. National laboratories, universities and other governmental organisations in other countries served similar roles. For much of the 20th century plant breeders in public institutions across the developed world created improved varieties and freely exchanged their materials. The understanding was that breeders would benefit from what they produced but all were free to build upon the work of others to make further improvements and call the resulting new varieties their own.

Private seed companies were founded to profit from the sale of high-quality seed, but they respected the *de facto* code of public sector plant breeders. Indeed, the public sector was a reliable source of improved materials for private seed companies to use to tailor varieties for a wide range of markets. The expertise of public plant breeders and the ability of companies to mass-produce and commercialise large volumes of high-quality seed turned out to be a powerful complementary and synergistic relationship. This situation flourished until the late 20th century when important changes combined to stifle this system. Increased commercial investment led to less public sector investment intended to reduce duplication and potentially unfair competition using tax dollars.

A major consolidation of the seed industry resulted in it becoming cost effective for companies to invest in the more basic plant biology and genetics research needed to make

specific advances in plant breeding. The results of their work were treated as proprietary and often not shared with the broader plant-breeding community. Increasingly restrictive means, including patents in the USA, to protect what was now viewed as intellectual property constrained the flow of new knowledge and germplasm to the broader community. The protection of intellectual property associated with crop varieties was not limited to the private sector. As public funding for plant breeding began to shrink late in the last century, public plant breeders were increasingly required by their institutions to protect and license their materials. In some ways as a reaction to the consolidation of the seed industry and considering naturally occurring variation in plants as intellectual property, the Convention on Biological diversity, along with the cascading myriad of agreements, protocols, treaties and national regulations around it, and outlined in the first section of this book, formalised and severely reduced the free exchange of genetic resources.

The advent of transgenic crops, or ‘genetically modified organisms’ (GMOs) added a further constraint to plant breeding. Fears of unknown consequences of adding ‘foreign’ genes to crops combined with concerns around concentration of plant breeding and control over national or global food supplies by multinational seed companies resulted in a highly restrictive regulatory regime in the European community, Africa, eastern Asia and, to a lesser degree, in Australia and North and South America. Fear of unintended environmental and human health impacts and multinational control over our food supply are common criticism raised about GMO crops. The unintended impact of the tight regulations is that only the largest companies can afford the very high costs of taking a potential product through the regulatory process to market. Chapter 11 critically examines the reasoning behind GMO regulation in the context of the many different current and likely crops and other agricultural applications.

Chapter 10 describes how public sector breeding programs have responded to this changing environment. The intricacies of public plant-breeding programs are inescapably the realm of specialists and require constant refinement, as the examples clearly show. The chapter also points out the need for public breeding programs to tackle the needs of crops that do not yet offer markets attractive to private investment. Much of the basic research in plant genetics that remains the province of the public sector must be adapted by plant breeders for it to be useful in breeding programs. This pre-breeding work for many crops is still beyond the scope of all but the largest private breeding programs. It is noteworthy that, even for crops with enormous markets in developed countries such as maize, soybean and cotton, there remain significant public breeding programs. But the nature of the research conducted today, as pointed out in Chapter 10, is very different from that of 50 years ago. A key argument for continued public investment in plant breeding is the need to train young scientists in the background biology, field methods and statistics needed be able to incorporate the growing understanding of plant biology and genetics into new crop varieties. An important question that emerges is of the proper balance between costs or risks to be borne by the public sector and gain to be enjoyed by the private sector.

Chapter 12 takes the reader through a fascinating account of the technical changes in plant breeding. This applies not only to breeding, but also to the better understanding of plant genetic resources. It illustrates how revolutions in microelectronics, global positioning systems, ‘big data’ management, computer modelling and remote sensing combine to open new opportunities to understand the complex relationships between crop genetics (genotypes) and field performance under differing environments (phenotypes). Chapter 13 presents a real-world demonstration of how a much more precise understanding of this genotype \times phenotype \times environment relationship has allowed breeders to develop rice

varieties that perform well under severe environmental stresses that previously often led to total crop loss. This chapter also critiques mainstream public plant-breeding programs in many developing countries. The uncomfortable conclusion is that breeding programs in developing countries, including most of those managed by international agricultural research centres, have fallen woefully behind the leading private sector breeding programs.

Chapter 11 provides several excellent examples of how modern and very costly techniques are being applied, and major breakthroughs achieved, in plant breeding by the private sector. These reinforce treatments elsewhere in this book of human nutrition, crop protection, stress tolerance and public policy, albeit from a very different perspective. It also lays out the perspectives of the private sector on the constraints imposed on crop improvement by the regulatory environment in some detail. While recognising the need to regulate a number of technologies, particularly those involving release of toxic compounds into the environment, a compelling case is made for re-examining how regulations are developed. Competing political, philosophical and technical concerns have become so entangled as to stymie technological advances. Rather than nitpick over the failings of the current regulatory frameworks in place in many countries, Chapter 11 takes the reader back to first principles and develops a compelling and thorough case for restructuring our necessary regulations based on the eight 'principles of good regulation' laid out by the Organization for Economic Cooperation and Development (OECD). This is very satisfying food for thought.