Productive Use of Scientific Plant Breeding: A Way Forward

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INTRODUCTION

The twentieth century therefore saw the production of high yielding cultivars by appropriate artificial hybridization and selection: clonal cultivars from multistage, 630 Epilogue multi-trait selection; hybrid cultivars from inbreeding and crossbreeding; and inbred line cultivars from hybridization and inbreeding. Continued progress was made by cycles of hybridization and selection, usually among the developing elite germplasm. Sometimes new traits were required for new environments, new end uses, and new pest and disease problems, and sometimes broader genetic bases were sought to deal with perceived plateaus in progress.

The development of scientific plant breedingwas based on an understanding of the mating systems of crop plants and the mechanism of inheritance, the legacies of Darwin and Mendel, respectively. In other words, an understanding of the genetic makeup of the gametes produced during meiosis (new combinations of alleles) and how these gametes are combined through the mating system to produce offspring with new genotypes and hence desired phenotypes (traits). Effective plant breeding also required the ability to recognize and hence select these new genotypes.

The twentieth century saw limited use of wild relatives in introgression breeding and landraces in base broadening as well as limited use of mutation breeding for special purposes. Finally, from the late 1970s breeders started to benefit in their selection programmes from the exciting developments in molecular biology, including the use of molecular markers to assist introgression breeding and to dissect complex traits such as yield.

Breeders currently face the challenge of how best to prioritize and integrate DNA selection of desired alleles for qualitative traits and ones of large effect at QTLs (Quantitative Trait Loci) with field selection for quantitative traits; having first ensured that they are present among the parental germplasm.

A new challenge is if and when to integrate genomic selection of quantitative traits. As a training population needs to be phenotyped as well as genotyped, a prerequisite may be the high throughput phenotyping methods currently being developed for use in the field.

Further improvements to successful cultivars can be made by genetic transformation and the production of genetically modified (GM) crops, with marker-free transformants and the ability to stack combinations of transgenes already realities. Furthermore, site-directed DNA sequence modification is now also becoming a reality; witness for example the current excitement over the CRISPR/Cas9 system for plant genome editing. The future scope of GM crops will increase with more detailed understanding of the biochemistry of a greater number of economically important traits.

The pace of technological advance quickened from 1995 with miniaturized microarrays for gene expression profiling of thousands of genes in parallel, and from 2004 with "Next-Generation Sequencing (NGS)" methods which dramatically increased the speed at which genomes could be sequenced. The result has been an equally rapid increase in knowledge of the genomes of cultivated plants and their evolutionary histories. Breeders starting work in 2015 will no doubt benefit from this increased genetic knowledge and combine it with the technological advances to aid the discovery of desirable genes (alleles) and to make breeding faster, more efficient and more effective at achieving desired goals. But technology alone will not be sufficient to meet the challenges of 2050. Breeders, as always, will need to apply appropriate breeding methods to the right germplasm for the right objectives, but the latter will depend upon answering the big questions about the most appropriate farming systems and most appropriate uses of crops for 2050.

Plant breeding will continue to be highly dependent on classical techniques but will undoubtedly increase in efficiency and effectiveness by the addition of these new approaches, which will be used in parallel with the more classical ones. Thus, the future will see the range of techniques expanding in such a way as to maximize their benefits by their integrated exploitation.

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