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Editorial:

Breeding crops by design for future agriculture

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Plant breeding is both the science and art of developing elite crop cultivars by creating and reassembling desirable inherited traits for human benefit. From the bulk selection of wild plants for cultivation during early civilization to Mendelian genetics and genomics-assisted breeding in modern society, breeding methodologies have evolved over the last thousand years. In the past few decades, the “Green Revolution” through breeding of semi-dwarf wheat and rice varieties, and the use of heterosis and transgenic crops have dramatically enhanced crop productivity and helped prevent widespread famine (Hickey et al., 2019). Integration of these technologies can significantly improve breeding efficiency in the development of super crop varieties (Li et al., 2018). For example, a hybrid cotton variety CCRI63 and six related hybrid varieties account for nearly 90% of cotton production in the Yangtze River Basin (Wan et al., 2017; Wang et al., 2018). These varieties have successfully combined high yield, good quality, and biotic stress tolerance through the integration of conventional breeding, hybrid and genetically modified organism (GMO) technologies (Lu et al., 2019; Ma et al., 2019; Song et al., 2019). Unfortunately, such technology integration is not practical for most staple food crops, including rice and wheat, because of social or technical restrictions. Furthermore, plant breeding is still labor-intensive and time-consuming, and conventional breeding remains the leading approach for the release of commercial crop varieties worldwide. This is especially true for breeding cultivars and hybrids with high yield, good quality, and resistance to biotic or abiotic stresses (Liu et al., 2015; Gu et al., 2016). New germplasm, knowledge, and breeding techniques are required to breed the next generation of crop varieties.

In this issue

Environmental stress is a major limiting factor in achieving maximum yield potential in crops. Climate change will further worsen this scenario. For example, salinity-affected areas will reach more than 50% of the world’s total arable land by 2050 (Mwando et al., 2020). Huang et al. (2020) integrate their research in barley and the latest progress in other plant species to identify the important role of ion transporters in salt tolerance and discuss the genome editing perspective for breeding high-salt-tolerant cultivars.

Food safety problems, such as those posed by heavy metal contamination, are other key challenges for future agriculture (Tang et al., 2018). In the following review, Chen and Wu (2020) summarize the genes mediating Cd transport (ion transporters and chelates) and molecular markers for low-Cd accumulation and discuss methodologies for breeding low-Cd cultivars. As Cd is a nonessential and toxic element for plants, the uptake and transport of Cd mainly rely on the transport system of essential mineral elements, such as Mn, Zn, Fe, and Ca (Clemens and Ma, 2016). How to breed a cultivar with low-Cd accumulation and simultaneously preserve mineral nutrient efficiencies requires more effort to understand the systemic regulation of plants.

Gene technology will play an essential role. Tan et al. (2020) summarize the current state of plant gene biology research from gene structure to multi-level

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regulation and propose various gene-editing strategies for coding and non-coding genes to create novel alleles for a particular purpose (Zong et al., 2018; Hua et al., 2019). In addition, ribonucleoprotein (RNP)-based protoplast editing may enhance genome editing efficiency (Woo et al., 2015).

Perspectives

It is a formidable challenge for future agriculture to maintain sustainable food production and satisfy the requirements for biofortification and safety of edible crops under a changing climate (Tang et al., 2018; Fernie and Yan, 2019). In a recent report, "Science Breakthroughs to Advance Food and Agricultural Research by 2030" (National Academies of Sciences, Engineering, and Medicine, 2019), genomics and precision breeding were identified as scientific breakthrough areas that will have the greatest positive impact on food and agriculture. Advances in sequencing technology are the cornerstone for genomics, having decoded the genomes of hundreds of species and uncovered the regulation network of complex traits (Jiao et al., 2017; Mascher et al., 2017; Song et al., 2019; Li et al., 2020). The resequencing of large numbers of crop germplasm provides a blueprint for identifying important genes and designing future varieties through genomics-assisted breeding (Lu et al., 2019; Ma et al., 2019; Song et al., 2019). High-throughput phenotyping technology is essential for understanding the economic value of genomic variations. Artificial intelligence for multi-scale phenotyping (i.e., phenomics) will provide high efficiency and accurate solutions (Araus et al., 2018). Rapid generation advancement or "speed breeding" will facilitate the transfer of technological advances to crop varieties in the future (Ghosh et al., 2018; Watson et al., 2018). Finally, gene editing will provide precision breeding technology to improve desirable characteristics (Shan et al., 2014; Svitashev et al., 2016; Liang et al., 2017). Multiplex editing may be possible soon using the similar technology developed for GMO crop (Liu et al., 2018). This will shorten the breeding cycle by incorporating speed breeding and tissue-culture-free techniques (Maher et al., 2020). However, none of the above technologies alone will be the silver bullet to breed climate-resilient crop varieties for future agriculture. A systematic approach needs to be adopted to integrate the technologies, including policy changes for gene-editing crops.

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