Editorial

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Flourish with the wild

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The wild relatives of our modern crops are of inestimable importance. Their domestication promoted the rise of civilizations and shaped cultures, and they are treasure troves for maintaining food security. However, shrinkage of their populations worldwide demands better conservation to retain their valuable biodiversity.

Crop wild relatives (CWRs) are direct ancestors of, or closely related species to, modern crops. In the eyes of ordinary people, they are inconspicuous and unattractive, and can be easily likened to weeds at the edges of fields or low-yield woody plants bearing sour fruits. They are 'inferior' plants lacking immediate economic value, but their importance to human societies can never be overstated.

Not any plant can be a wild relative of a crop. Since agriculture began, roughly 12,000 years ago, humans have explored the use of nearly 10,000 plant species for food and fodder production[1]. Only about 150 of these species yielded useful domesticates, and a smaller subset of 15 major crops became staples. The limited geographical distributions of prehistoric CWRs largely determines the pattern of today's world.

As Jared Diamond proposed in his famous book, *Guns, Germs, and Steel*, people of Eurasian origin dominated the world in wealth and power because of opportunity rather than superior intelligence[2]. Much of this opportunity came from the luck that important wild domesticable plants emerged in this continent, but not elsewhere, specifically in the Fertile Crescent of the Middle East and the Yangtze and Yellow River valleys of China. The easy access to these CWRs offered opportunities for establishing stable agricultural societies. It is not just about feeding people; food surpluses liberated people from subsistence and supporting population growth, enabling them to specialize in activities, ultimately driving social and technological innovations[2]. Fortunately, the east-west orientation of this continent meant that crop transmit and agriculture spread easily.

In an Article in this issue, Zhao et al. leverage population genomic analyses in order to delineate one of these opportune events — the early domestication and spread of wheat. They localized the origin of bread wheat to the southwest of the Caspian Sea and estimated a speciation process in Fertile Crescent lasting 3,300 years when its genome was shaped by genetic crossings with its wild relatives. Subsequently, bread wheat spread via four routes to other areas of Eurasia. Archaeologists have already found that wheat, together with barley, often travelled as part of the 'Neolithic package' of mobile pastoralists, and this spread had apparently facilitated the exchange between cultures and the thriving of ancient Eurasian states.

Similarly, Chinese civilization was built on the ample wild rice diversity on the Yangtze riverbank. The domestication of rice occurred between 9,000 and 10,000 years ago, but specifically where and how many times it was domesticated remains controversial. Nevertheless, what is indisputable is that the domestication, spread and diversification of rice across Asia have tremendously influenced the economies and cultures of Asian peoples. The need for organized and reliable irrigation associated with rice farming promoted the development of centralized states in these areas and is probably responsible for the collectivist mindset of East Asia.

For people living in a world that has been industrialized and 'informationized', CWRs remain just as important. The UN predicts that the global population will reach 10 billion people in 2057. At the same time, climate change is becoming even more pronounced and extreme weather events even more prevalent. Food security is no less important today than in agricultural society. Our crops domesticated from their wild progenitors all experienced a genetic bottleneck that eroded their diversity. Consequently, resistance and yield-related genes must be borrowed from the wild. Induced mutagenesis may generate novel alleles, but breeding still chiefly relies on the vast amount of existing variation. For many crops, enormous diversity has been found in their wild relatives, encompassing tolerances to biotic stresses (for example, insects, diseases and weeds) and abiotic stresses (for example, drought, flood, heat and salt)[3], which have been exploited in breeding. The male sterility gene discovered in wild rice and later deployed in hybrid rice nearly doubled rice production in the last century.

However, genes in urgent need are not always available in the wild. For example, the most devastating and yet incurable bacterial disease of citrus, Huanglongbing, is highly infectious and caused severe symptoms to tree leaves and vascular systems. No resistant citrus genotypes have been found in the wild relatives, so scientists are hunting for resistance in more distinct relatives, for instance in the tribe Citrinae. However, these are sexually incompatible with citrus, and thus the possibility of grafting as resistant rootstock is now being explored.

Papaya ringspot virus is another catastrophic pathogen that nearly destroyed the papaya industry last century. Originally found in Hawaii, it caused severe symptoms including leaf distortion, fruit ringspots, systemic necrosis and wilting. Again, no natural resistance existed. If it wasn't for gene silencing technology, this fruit may have already disappeared from our diets. This crisis showed how helpless such a situation could be without usable natural variations. The intrinsic vulnerability of many tree crops, such as rubber trees and banana trees, which is due to their super low genetic diversity, renders conservation of their CWRs exceptionally important.

CWRs also make perfect subjects in research, especially for advancing our knowledge of domestication and polyploids, which further benefits breeding. Plenty of genetic studies have used CWRs to clone domestication genes, the knowledge of which promoted the understanding of domestication and enabled de novo domestication. For instance, tetraploid rice and groundcherry were recently domesticated by editing the homologues of domestication genes in CWRs using CRISPR[4,5]. Knowledge of the domestication processes of polyploid crops also allows generation of synthetic new crops, such as synthetic polyploid wheat, Brassica and cotton, which are valuable research and breeding plant materials[6].

Unfortunately, the importance and usage of CWRs does not prevent the shrinking or extinction of their populations. Demographic inference in Zhao et al's Article suggested wheat relative populations retained less than 20% diversity in the past approximately 2,000 years due to human diet shift, and their modelling predicted a continuous contraction of many wheat relatives due to climate change. Similarly, for rice, land use change and habitat destruction depleted more than half of their wild populations over only forty years in countries like China and Thailand[7,8]. Moreover, the largest teosinte populations are now fragmented and significantly diminished too[9], with several of its wild in situ preserved populations, including the ones in Guatemala, already extinct[9,10]. Apart from population disappearance, frequent gene flows from cultivars often dilute the CWR gene pool, representing another form of genetic erosion.

The loss of these wild genes means permanent loss if no ex situ conservation has been set up for them. Thorough surveys as well as systematic and sophisticated in situ conservation, combined with ex situ preservation strategies, are needed for better discovery and protection of natural populations. Although it is commendable that multiple nations have realized the importance of CWRs and made substantial efforts in conservation actions[11], there's still a large gap[12], particularly in ex situ conservation. Globally, over 70% of CWR taxa were estimated to be poorly represented in gene banks[13], and this situation is not more optimistic in the most developed countries like the USA[12].

Having benefited humans in many ways, CWRs still hold the key to safeguarding our future. To ensure a sustainable development of human societies, proper conservation is essential, but it seems a heavy responsibility and a long road.

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