

mitochondria during the interphase stage of the cell cycle, which precedes mitosis. It will be important to discover whether mitochondrial movement, interconnectivity and dispersion are processes that mutually affect each other.

Certain types of cell divide asymmetrically and generate daughter cells with different fates. During the division of a stem cell, the older mitochondria in the dividing cell are preferentially partitioned to the daughter cell that is destined to differentiate, whereas the younger and 'fitter' mitochondria are apportioned to the daughter cell that maintains stem-cell properties<sup>10</sup>. One can predict, therefore, that mitochondria mixing is suppressed in these cells and that other, as yet unknown, mechanisms ensure the asymmetric inheritance of mitochondria. Clearly, mitochondrial research will yield many more surprises in the future.

## Genomics

# Sowing the seeds of multi-genome rice

Diane R. Wang

Having more than two sets of chromosomes can help plants to adapt and evolve, but generating new crops with this type of genome is challenging. A road map for doing just that has now been developed using wild rice.

We all sometimes wish we could do more than one thing at once – run errands, catch up on work deadlines and perhaps grab that long-overdue coffee with a friend. A genetic state known as polyploidy helps some plant genomes to do just this. Most plants, like humans, are diploid, with two sets of every chromosome. But polyploid plants have four, six or even eight sets of chromosomes. These additions allow different copies of a gene to take on different roles, and provide a buffer against potentially harmful mutations. Accordingly, polyploidy has served as a common mode of evolution in flowering plants<sup>1</sup>. Writing in *Cell*, Yu *et al.*<sup>2</sup> outline a viable approach to producing a domesticated form of polyploid rice using gene editing. Their advance could allow us to reap the benefits of polyploidy in one of the world's most important crop species.

All crop species evolved from wild ancestors, as humans saved and propagated plants that had favourable attributes – loss of seed-dispersal mechanisms, for instance, and larger seeds and fruits<sup>3</sup> – over hundreds or thousands of years. The world's main rice crop, the Asian species *Oryza sativa*, was domesticated

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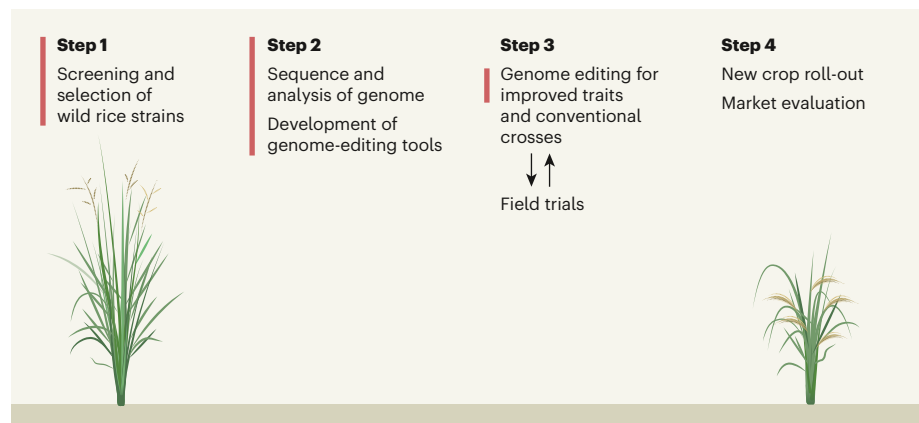
carrying two sets of 12 chromosomes.

For rice scientists, the idea of developing polyploid cultivated rice is tantalizing as a potential means for future crop improvement, especially in the face of climate variability<sup>6</sup>. The plant's extra gene copies might enable rapid adaptation in response to major changes in the environment without the loss of favourable features<sup>7</sup>. But generating a polyploid rice from a cultivated diploid plant is hugely technically challenging. With that in mind, Yu *et al.* took an entirely different approach. The authors started with a distant, wild polyploid cousin of *O. sativa* and *O. rufipogon*, and domesticated it using biotechnological approaches (Fig. 1).

The authors first spent time identifying an appropriate starting strain. The ideal candidate needed to be amenable to callus induction and regeneration – a process in which plant tissues are cultured to produce a mass of partially undifferentiated cells called a callus, from which new plants are generated. These properties are essential for gene-editing techniques. The selected individual also needed to have high biomass and tolerance to various abiotic and biotic stresses – heat and insect resistance, for example. After screening 28 polyploid wild rice lines, a strain of *Oryza alta* was selected, and named polyploid rice 1 (PPR1).

*Oryza alta* has four sets of chromosomes (it is tetraploid), and is found in Central and South America<sup>8</sup>. The species arose as a result of hybridization between two ancestors that had diploid genomes, designated C and D. The PPR1 strain selected by Yu *et al.* looks quite different from cultivated *O. sativa*. For instance, it is very tall – more than 2.7 metres, compared with 1 metre or less for typical *O. sativa*. It produces abundant biomass, and has broad leaves and sparse, small seeds adorned with awns (spiky protrusions thought to aid seed dissemination). As such,

about 9,000 years ago from its wild progenitor, *Oryza rufipogon*, through processes thought to have occurred across multiple regions in Asia<sup>4,5</sup>. Both species are diploid,



**Figure 1 | A fast track to cultivated polyploid rice.** Yu *et al.*<sup>2</sup> have developed a strategy for rapid domestication of wild polyploid rice (which has more than two sets of chromosomes, unlike the rice commonly grown as a food crop). The first step is to select a wild strain that has favourable characteristics for gene editing and crop production. This is followed by genomic analysis and method optimization. Iterative cycles of genome editing, conventional crossing and testing are then needed before the new crop is rolled out to farmers and evaluated. Red highlights indicate sections of the road map completed by the authors for the wild rice *Oryza alta*.

## News & views

domesticating this wild relative was no small feat.

Yu and colleagues established methods for gene editing in PPRI, and assembled a high-quality genome for the strain. This acted as a map that helped identify genes to target for domestication. The authors compared PPRI with an *O. sativa* genome dubbed Nipponbare. They discovered about 10,000 genes in each of the C and D genomes that did not have equivalents (homologues) in Nipponbare. By contrast, about 39,500 genes in Nipponbare (70.41% of the genome) did have homologues in PPRI.

The latter was a promising result, because it meant that the genes responsible for domestication in *O. sativa* probably had related versions in PPRI. The researchers edited a suite of such genes in PPRI that were known to have been involved in the domestication of *O. sativa*. This led to a range of improvements in PPRI: loss of shattering (a seed-dispersal mechanism), so that seeds did not fall off the plant before harvest; reduced awn length to ease post-harvest processing; increased grain length for larger kernels and greater yield; decreased height and thickened stem diameter to support the heavier grains; and modified (both longer and shorter) flowering times, needed for local adaptation to different latitudes.

Together, Yu and colleagues' efforts led to

the production of PPRI lines with domesticated features in a just few generations, fast-tracking a process that typically occurs over hundreds to thousands of years. The work opens the door to developing plants that not only can better withstand environmental stresses (a crucial characteristic for global food security in the face of changing climates), but also could carry other characteristics – enhanced nutrition and taste, for example – that might help rice to meet evolving consumer preferences in the future. In addition, the strategy the authors have devised could theoretically provide a road map for applying biotechnology to drive the domestication of wild relatives of other present-day crops.

The techniques established by Yu *et al.* await testing in other wild, tetraploid rice strains. Successful extension to a broader gene pool will be necessary if researchers and breeders are to generate a diverse repository of domesticated polyploids, which could then be used to generate further improved strains through conventional crosses or genome editing – strains adapted to particular production systems, for instance, or those with high market acceptability. And although wild polyploids hold great promise as yet-untapped sources of genes that confer tolerance to abiotic stresses such as drought, these traits are likely to be complex, as noted by the authors, being influenced by many genes, each of which has only

a small effect. A deeper understanding of the genetics of these plants is needed for the full potential of wild rices to be appreciated.

There is a long journey ahead for the breeding of cultivated polyploid rice. But the first seeds have now been sown. As demand for nimble and resilient food systems rises, rapid domestication and improvement of wild plant species, including polyploids, may well become a valuable instrument in agriculture's toolbox.

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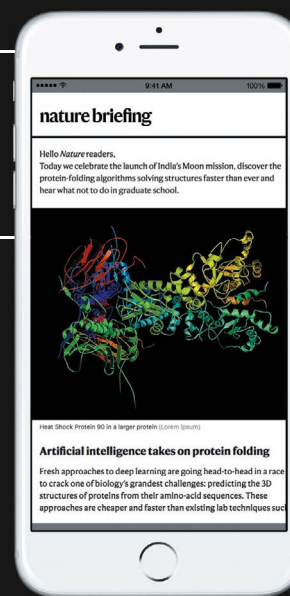
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