Extra genomes helped plants to survive extinction event that killed dinosaurs

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Sixty-five million years ago, life on Earth was sorely tested. One or more catastrophic events including a massive asteroid strike and increased volcanic activity, created wildfires on a global scale and dust clouds that cut the planet's surface off from the sun's vital light. The majority of animal species went extinct including, most famously, the dinosaurs. The fate of the planet's plants is less familiar, but 60% of those also perished. What separated the survivors from the deceased? How did some species cross this so-called "K/T boundary"?

Jeffrey Fawcett form the Flanders Institute for Biotechnology thinks that the answer lies in their genomes and specifically how many copies they have. Geneticists have found that the majority of plants have duplicated their entire portfolio of genetic material at some point in their evolution. They are called "polyploids" - species with multiple copies of the same genome.

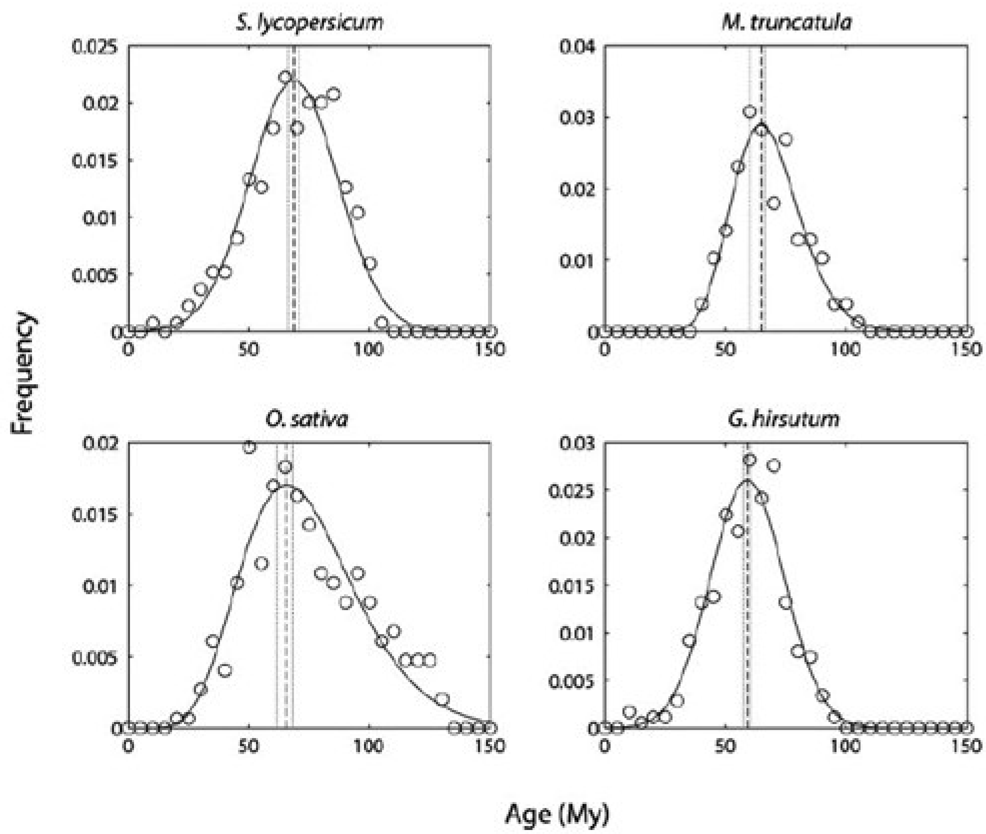
By dating these doublings, Fawcett had found that the most recent of them cluster at a specific point in geological time - 65 million years ago, at the K/T boundary. It suggests that having extra copies of their genomes on hand gave these plants the edge they needed to cope with the dramatic environmental changes that wiped out the dinosaurs and other less well-endowed species.

Time and again, scientists have found that flowering plants, from trees to grasses, have multiple copies of their genomes. The exact number and timings are being debated, but most agree that the oldest doubling took place very early on in the evolution of this group. It may even have contributed to the lineage's success. Within about 5 million years, the lineages that would eventually produce about 97% of all flowering plant species had exploded into existence and an extra genome copy may have acted as the catalyst for this rapid expansion.

But this ancient doubling was just the beginning. Recent studies have found evidence of another, more recent duplication in the genomes of many species. To date these events, Fawcett looked at several plant species whose entire genomes have been completely sequenced - the thale cress *Arabidopsis*, the California poplar, barrel clover the common grape vine and rice - and many others that we have plenty of genetic data for, including cotton, tomato, lettuce, Californian poppy and American sweet flag.

Fawcett used these sequences to build a family tree of these different species. He used known evolutionary splits to put dates on the tree's branches and he used this information in turn to date the recent genome duplications in the various species.

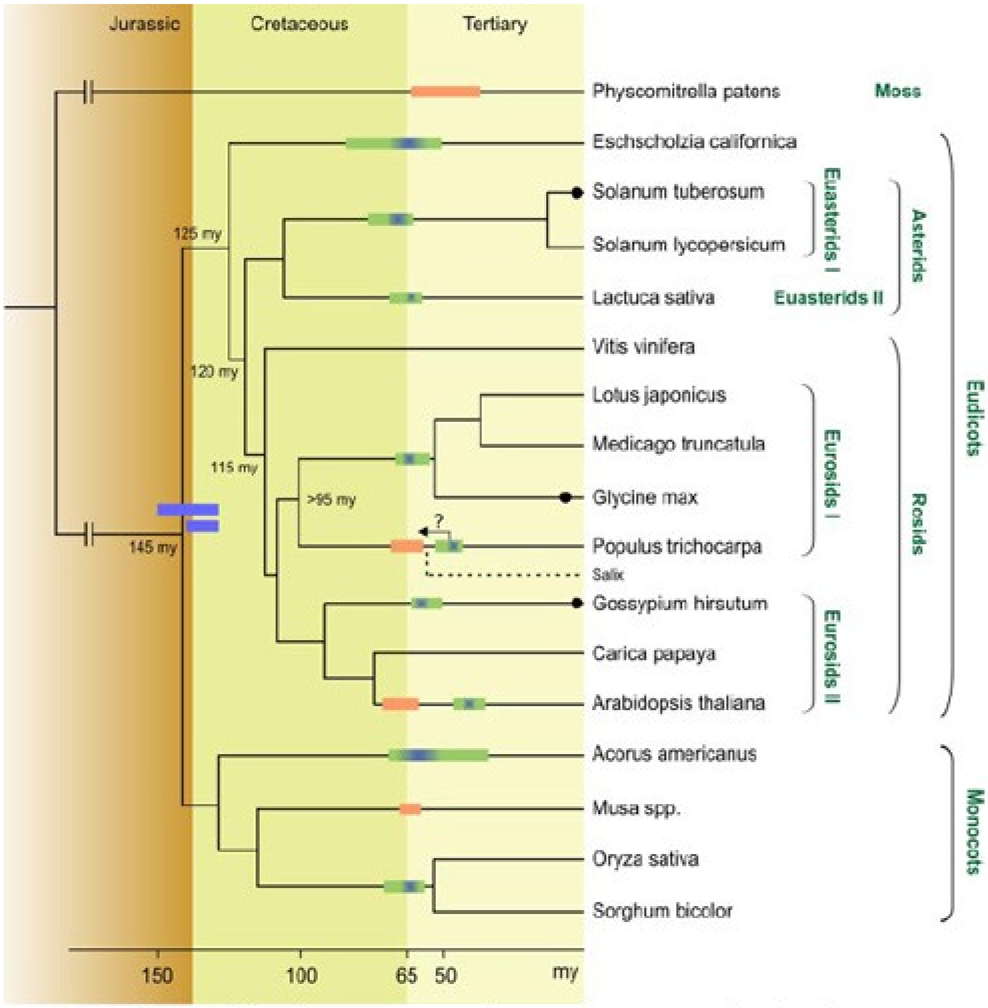
In almost all cases, from rice to tomatoes to cotton, flowering plants showed a peak in or genetic duplication between 60 and 70 million years ago - a time that precisely matches the Earth's most recent mass extinction. Ten million years may seem like a long time to us but geologically it's a blip. The world's climate was changing long before the asteroid impact that truly sparked the extinction event, and the strike's aftermath lasted long after it happened.



Fawcett recognises that dating these events can be an unexact science, but he feels that the cluster of dates round this point is significant and unlikely to change. Only *Arabidopsis* and the poplar didn't fit this narrow band of time - they most recent genome duplications took place about 43 and 48 million years ago respectively.

In the case of *Arabidopsis*, Fawcett cites another study which suggests that this species, so favoured of geneticists, has copied its entire genome twice in the last 70 million years. It may be that this current study has only picked up the most recent event. In the case of the poplar, its family of trees have a tendency to evolve very slowly, which may mean that Fawcett's methods underestimated the date of its most recent whole-genome duplication.

During the KT boundary, the planet's environment changed dramatically. Dust clouds thrown up by asteroid collisions would have choked plants of sunlight and led to freezing ground temperatures that prevented seeds from germinating. There's plenty of evidence that these prehistoric plants were severely hit by these conditions. Studies of fossilised pollen, spores and leaves have suggested about 60% of plant species went extinct, including a "global forest dieback". The abundance of decaying vegetation provided nourishment for fungi, and their populations boomed at the KT boundary.



Green/blue bars represent recent genome duplications
Orange bars are estimates taken from other studies

Fawcett thinks that double-genomes provided some lineages of plants with advantages that saw them through the environmental upheaval. Some studies have suggested that plants with multiple copies of their genomes are better able to cope with changing environmental conditions. Spare copies kicking around mean that the plant is more resistant to harmful mutations cropping up in any one gene.

But far from just being identical back-ups, spare copies can also be repurposed to new jobs or be used in new locations and at new times. This division of labour can be set up very quickly and provides the plant with the ability to swiftly adapt to new conditions - they get more bang for their genetic buck. You can see this happening in artificial selection experiments - cotton plants partition different copies of the same gene towards different ends if they are placed in difficult environments, like cold or too much water. By doing this, the plant ensures that neither copy is redundant; both quickly take on important roles and evolve independently.

Finally, plants with extra genome copies find it difficult to mate with other individuals with just the one, so they are biased towards fertilising themselves and reproducing asexually. That could actually be a perk in an environment where populations are crashing and mates are becoming scarce.

All these benefits combined to give polyploid plants a valuable advantage in a harsh world. Perhaps even further genome duplications will give some plants an edge in the rapidly changing climate of 21st century Earth.

There are signs that this might happen. The Arctic Circle is a haven for polyploid plants and there's evidence to suggest that those with many genome copies are better than those with just the one at colonising areas where glaciers have vanished More recently, the industrial wastelands of York have been colonised by a new species of plant, the York groundsel, that evolved when two other species - the Oxford ragwort and common groundsel - crossbred to form a polyploidy hybrid.

Reference: PNAS doi:10.1073/pnas.0900906106 to be published this week