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Seed Dispersion

Prof. Ewelina Ratajczak, PhD, DSc
specializes in the physiology and biochemistry of seeds. An Associate Professor at the PAS Institute of Dendrology, she studies the molecular foundations of deterioration of tree seeds and compounds regulating redox in seeds, looking for potential markers of their viability.
eratajcz@man.poznan.pl

Hanna Fuchs, PhD
studies the processes behind the deterioration of tree seeds and factors affecting their viability on the molecular level at the PAS Institute of Dendrology. She is especially interested in plant genetics and identification of genes responsible for the acquired resistance to overdrying of seeds.
hkijak@man.poznan.pl

Sycamore maple seeds, with visible wings

What strategies do plants use in trying to disperse their seeds, so as to colonize distant areas? Is it more advantageous to have tiny seeds as light as a feather, or tough and heavy acorns?

Ewelina Ratajczak
Hanna Fuchs
Joanna Kijowska-Oberc
Jan Suszka

PAS Institute of Dendrology in Kórnik

Aleksandra M. Staszak

Faculty of Biology University of Bialystok

Plants surround us, dominating the landscape and accompanying us in our everyday lives. Without plants we would have no food, construction materials, or energy sources. But notice that in contrast to animals, plants have a limited ability to change their habitat – in fact, the only way most plants are able to migrate is in the form of seeds. Seeds contain the genetic material of the plants that produced them, and after they are released, given the right conditions, they are able to germinate and thus expand the range of the species' population.

Trees, for instance, spread their genetic material via various routes, depending on the specific strategy of each species. One approach is illustrated by the light winged seeds of trees such as maple and ash, which are carried by the wind. Willows and poplars, common in Poland's river valleys, have tiny seeds with a ring of stiff hairs which can also be carried by the wind over long distances. These are typical pioneering species which produce vast numbers of seeds every year. After dispersal, if the seeds land on suitable ground, they start germinating quickly. Basket willow seeds, for example, lose their viability around nine days after dispersal. This is compensated for by the high volume of seeds released, although producing them absorbs a lot of energy.

Many, or few?

Species such as beech and oak, on the other hand, have developed a very different strategy for conquering new areas. With high mass and density, they rely on gravity for dispersal. Since such seeds fall close to the original tree, this may not seem like an ideal solution for conquering new territories. However, the heavy seeds of oaks, beech and chestnuts frequently rely on animals to provide "courier services." Other species making use such "couriers" include yews, raspberries, and cherries, which bear sweet fruit surrounding the seed. Birds and animals feed on the tasty fruit, and their digestive acids may help the seeds germinate once they are excreted.

Species which produce heavy seeds generally follow a reproductive cycle lasting between five and ten years, known as the masting cycle. A clear correlation can be seen between the reproductive cycles of certain rodent and bird species, and the masting cycles of the seeds that are the mainstay of their diet. These animals may be seen as reducing the reproductive capacity of mast-producing species, but they also provide valuable opportunities: they carry away nuts and acorns to store for later, then frequently forget about them. This opens up opportunities for colonizing new territories which would have been inaccessible without the animals' help.

Joanna Kijowska-Oberc, PhD

studies the impact of climate change on the quality of tree seeds and their germination at the PAS Institute of Dendrology. She is especially interested in mechanisms affecting how trees adapt to droughts and heatwaves, in particular epigenetics and phenotypic plasticity.

joberc@man.poznan.pl

Jan Suszka, PhD

specializes in the methodology of collecting and storing seeds, in particular recalcitrant and suborthodox seeds. He also conducts research into overcoming seed dormancy. He works at the Institute of Biology at the PAS Institute of Dendrology.

jsuszka@man.poznan.pl

The location of reactive oxygen species in beech seeds

Aleksandra M. Staszak, PhD
is a specialist in plant physiology at the Faculty of Biology at the University of Białystok. She studies the impact of various environmental factors on seed germination and interactions between plants and their pathogens.
a.staszak@uwb.edu.pl

Producing high volumes of seeds demands high energy output, which requires the tree to spend a few years regenerating. This means that between masting years, trees flower only sporadically, or not at all. The exact mechanisms that underpin the masting phenomenon are the subject of much discussion. The most pressing question is how climate change is affecting it. The answer is made all the more difficult by the fact that the plants under consideration live long lives; therefore, the impact of global warming on masting cycles has yet to become reflected in models forecasting changes to the future species composition of forests. However, certain tendencies have been observed in recent years, such as increased or decreased masting frequency and an imbalance in seed creation. Another complication is that higher or lower temperatures may be perceived by different trees as a signal for intense seed production. High temperatures induce flowering in the European beech and the ponderosa pine, but have a negative impact on the Siebold's beech and the Colorado pine. Mass flowering may also be triggered following periods of droughts or fires, which are becoming increasingly common in the changing climate.

While discussions about the long-term consequences of climate change on masting cycles are relatively recent, observations thus far suggest that global warming is likely to have a negative impact on seed production in trees. Both overproduction (reducing seed quality) and underproduction will lead to shortages of the reproductive material essential for maintaining the continuation of species and the survival of forests.

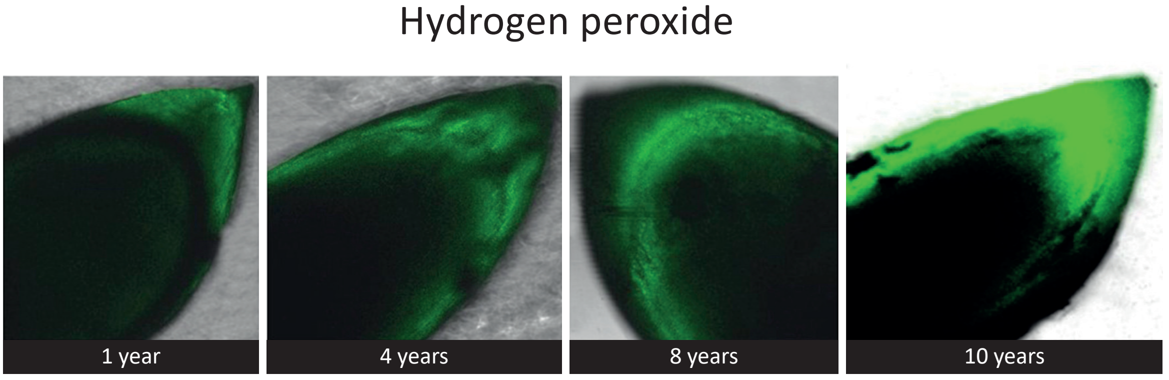
Helping populations shift location

In flowering plants (or "angiosperms"), the seed production cycle is completed within a single season. Pine and spruce trees ("gymnosperms"), which develop their seeds in cones, can take longer. In the Scots pine, for instance, the cycle from fertilization to the release of seeds takes three years, while in the spruce it takes around a year. In winter, spruce cones release winged seeds that get carried by the wind far away from the original tree, exploring distant spaces in search of a new ecological niche.

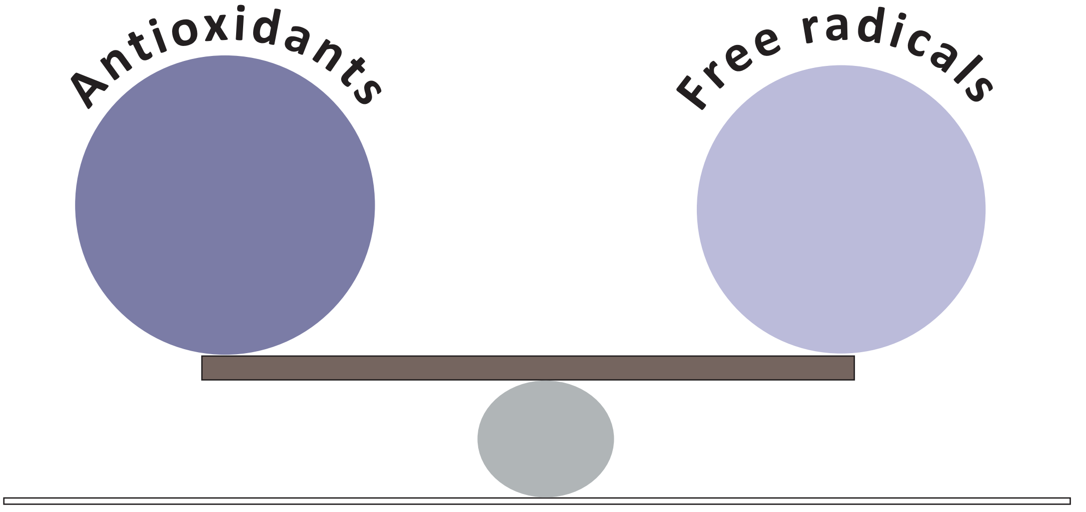
The climate has a long-term impact on trees and their seeds during development. Stress may limit plant development at various stages of their lifecycle, but it may also foster adaptive behavior. The ability of a new generation to survive in a hostile environment depends on local conditions. Seeds – the first developmental stage of trees – play an extremely important role in the process.

The consequences of water shortages and high temperatures extend deep into their cells at early stages, while they are still ripening on the original tree. Seed viability is highly important for the survival of the population and the species and their range. Climate change urges us to identify populations with highly viable seeds, able to give rise to forests which are more stable and resilient to new conditions. Until recently, a quick and popular test of seed viability involved dyeing germinating seeds with tetrazolium, which turns living tissue a bright red hue. Researchers also conduct germination tests to assess what percentage of seeds germinate into viable seedlings within a given time period.

Work in search of a biochemical marker of seed viability has led to the observation that as seeds of the Norway maple develop, they respond to rapid temperature changes and reduced rainfall by producing elevated levels of proline. Proline is an amino acid which accumulates in tissue in response to various kinds of stress; it can retain water in cells and protects their structures against damage. Research conducted on a range of tree species reveals that the leaves of seedlings of species which produce larger seeds accumulate higher levels of proline in response to droughts than those of species bearing smaller seeds. Can we say, therefore, that proline is an indicator of seed viability? The answer is rather



The *in situ* location of hydrogen peroxide in the germination axes of beech seeds preserved in storage



Equilibrium in the cell

complicated, and it requires analysis of the enzymes responsible for the synthesis of this fascinating amino acid.

Better understanding how forest tree species adapt to climate change is one of the greatest challenges facing contemporary forestry. It is likely that using seeds obtained from populations identified as being more resilient and producing more viable offspring will allow us to improve the quality of forests. If this strategy is employed in conjunction with the latest forecasts of climate change, we may be able to employ "assisted migration" – a deliberate act of moving a given population of species to a different habitat where they will be better adapted.

Space vs. seed physiology

Developing effective methods of storing seeds is important not only for agriculture, horticulture, and forestry, but also for gene banks that collect plant genetic material from various locations. Gene banks preserve plant seeds for future generations and facilitate broadly designed studies on samples collected at different times across a range of sites.

However, seeds kept in storage are at risk of deteriorating and losing their most important property: their ability to germinate. Researchers have been trying to identify the reasons for this deterioration and whether it can be counteracted. Research carried out at the PAS Institute of Dendrology reveals that vitality loss in beech seeds in long-term storage is driven by the accumulation of reactive oxygen species (ROS). An accumulation of ROS in the root apical meristem of the germination axis may halt cell division and prevent the seed from germinating. So what are ROS? In simple terms, they are atoms or clusters of atoms which contain an unpaired electron following an incomplete reduction of molecular oxygen. They are highly reactive and rapidly enter into reactions with cellular components, and when produced in excess they cause damage and can lead to cell death.

Non-reducing sugars such as sucrose and oligosaccharides from the raffinose series (raffinose or stachyose) are used as reserve material, accumulated during seed development and utilized in the first hours of germination. The most important role played by non-reducing sugars is to protect seed cells against water loss caused by drought or long-term storage. The substances maintain the vitality of beech seeds even when they are stored for many years. Given the rapid changes occurring in the environment, understanding the processes they cause in seeds is extremely important, and not just from the perspective of satisfying our scientific curiosity. The knowledge is especially important for preserving seed banks which are fundamental in forestry, agriculture, and horticulture.

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Climate change and its consequences have an impact on species distribution and range and numerous physiological processes, including germination. This translates into the reproductive potential of plants and their ability to maintain current habitats and find new ones. In turn, this affects the dynamics of entire populations and may ultimately decide their future in the rapidly changing environment. ■

Further reading:

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