■ Research Highlights

DNA as a 'reservoir' of phosphorus nutrient: Plants recycle DNA in chloroplasts as a source of phosphorus under starvation

It is well known that nitrogen, phosphorus, and potassium (NPK) are the three macro-nutrients necessary for plant growth, and are the main components of fertilizer. Among them, phosphorus has recently received global attention as it is derived from limited rock mining, and its overloading gives rise to water pollution. To resolve these problems, it is important for a deeper understanding of how crops (plants) efficiently use phosphorus. In cells phosphorus is incorporated as inorganic phosphate, and major phosphate-containing macromolecules include nucleic acids (DNA and RNA), phospholipids, and phosphoproteins.

In this study, Wataru Sakamoto and colleagues focused on DNAs kept in 'endosymbiotic organelles', namely, chloroplasts and mitochondria. These small organelles are considered to evolve from the endosymbiosis of ancestral bacteria, which happened in ca. 1.5 billion years ago. To support this evolution, it is known that remnant DNAs exist in these organelles. These organelle DNAs exist highly abundantly in chloroplasts, that accounts for more than 30% of total DNA in leaves. Sakamoto's group hypothesized that these extra DNAs in organelles could be degraded and recycled.

In this report they describe the enzyme called DPD1, that degrades organelle DNAs in a model plant, *Arabidopsis* and in poplar trees. DPD1 is well conserved among seed plants and degrades abundant chloroplast DNAs, when plants undergo 'senescence' or 'leaf fall', in which leaves degrade numerous macronutrients and recycle them in their upper tissues. Interestingly, *Arabidopsis* mutants lacking DPD1, when placed under phosphate-limited conditions, suffered from poor growth, produced less seeds, and disturbed less phosphorus relocation to upper tissues (Figure 1).

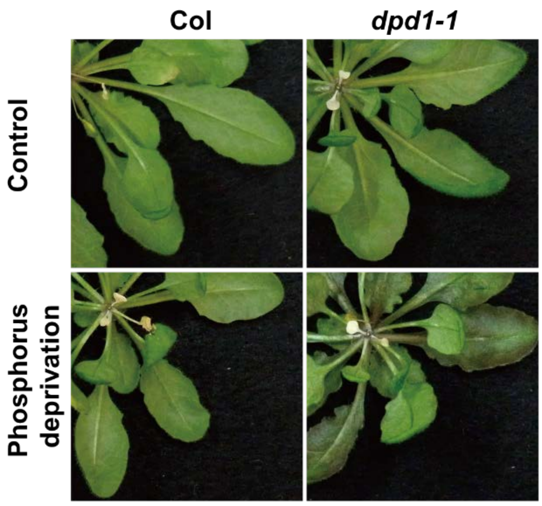

Figure 1. Purple leaf coloring observed as a typical symptom of phosphorus starvation. The Arabidopsis mutant lacking DPD1 nuclease (*dpd1-1*) displays purple leaves upon phosphorus starvation (right), where as the wild-type Arabidopsis plant (Col) does not. The results indicate that DPD1 acts in providing internal phosphorus, when plants are limited by external phosphorus.

The results obtained in this research revisit the old implication envisioned by Friedrich Miescher, a Swiss biochemist who first identified DNA biochemically in the late 19th century. He recognized DNA as a molecule enriched with phosphorus, unlike protein, and noted that DNA (he originally called it 'nuclein') might be a phosphor-storing molecule. Needless to say, DNA is well known to code genes, but his original thought on

DNA as a phosphor-storing molecule may thus be applicable to abundant organelle DNAs.

The findings uncover an elaborate way of adaptation to harsh environments in plants, which may lead to the improvement of crops connected to efficient phosphate use (Figure 2).

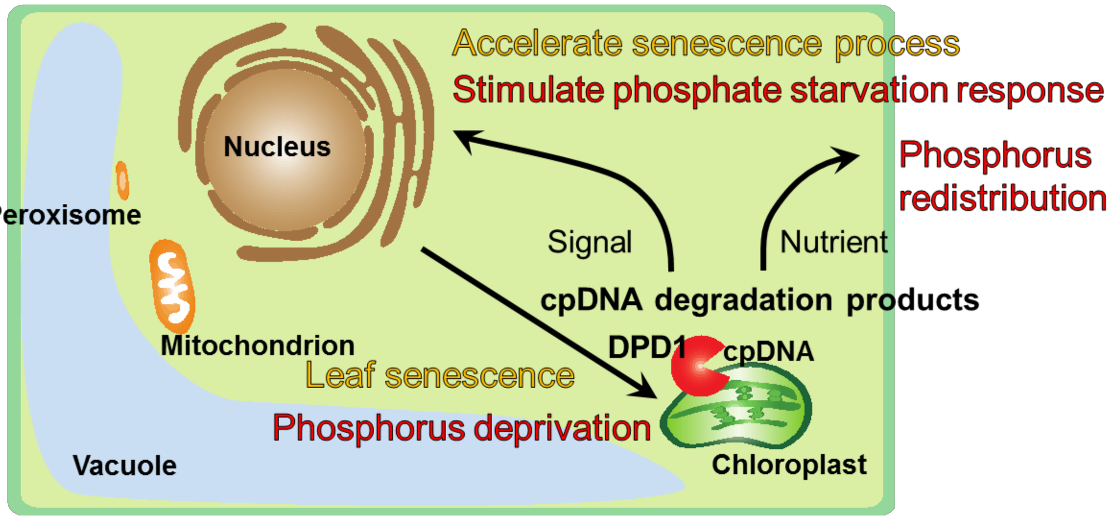

Figure 2. A proposed model of DPD1 exonuclease involved in leaf senescence and phosphorus deprivation. By degrading excessive chloroplast DNAs (cpDNAs), the degradation products may act in providing additional phospho-compounds to the upper tissues. The degradation products may also act in stimulating nuclear gene expression, that would lead to what is known as the response to phosphate starvation.

Reference:

- Authors**:** Tsuneaki Takami, Norikazu Ohnishi, Yuko Kurita, Shoko Iwamura, Miwa Ohnishi, Makoto Kusaba, Tetsuro Mimura, and Wataru Sakamoto
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