Safeguarding genome integrity in germination and seed longevity

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Successful germination is important for agriculture and plant survival in natural ecosystems. Deterioration in seed quality is associated with the accumulation of cellular damage to macromolecules including DNA. Striking levels of DNA damage are further increased in seeds exposed to environmental stresses associated with seed ageing. Genome integrity is crucial for cellular survival and the faithful transmission of genetic information and repair of damage in early germination is essential to minimise growth inhibition and mutation of the genome. We have discovered that maintenance of germination vigour and viability requires several distinct repair pathways specific for particular forms of DNA damage. In particular, mutants deficient in repair of highly cytotoxic chromosomal breaks are hypersensitive to seed ageing, and repair of DNA double-strand breaks (DSBs) is rate-limiting for germination. The crucial link between genome integrity and germination was further supported by our findings that the DNA damage signalling kinases ATAXIA TELANGIECTASIA MUTATED (ATM) and ATM AND RAD3-RELATED control seed vigour and viability. In response to ageing, ATM delays germination, whereas *atm* mutant seeds germinate in the presence of DNA damage, resulting in extensive chromosomal abnormalities. Mechanistically, ATM functions through control of DNA replication in imbibing seeds which is mediated by transcriptional control of the cell cycle inhibitor SIAMESE-RELATED 5. Our current research is revealing how DNA damage signalling integrates repair, cell cycle control and cell death in seeds. Collectively, our findings provide insight into the roles of genome maintenance mechanisms and DNA damage response networks in regulating germination, a process critical for plant survival in the natural environment and crop production. Understanding the mechanistic basis of seed vigour and viability will underpin the directed improvement of crop varieties with enhanced germination resilience and longevity, and support preservation of genetic resources in seedbanks.