ABSTRACT

Insights into Cold Stress Response Mechanisms of Asian Rice Subspecies and the Overexpression of *OsUBC7* for Improving Rice Cold Tolerance

Huy Minh Phan, B.Sc.

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By 2050, with the global population projected to reach 9.7 billion, food demand, especially for staple crops, will increase. Climate change worsens this by increasing extreme temperature fluctuations, and heavily impacts Asian rice (*Oryza sativa* L.), which are predominantly cultivated in tropical and subtropical areas, and highly susceptible to cold temperatures. Therefore, understanding the response mechanisms of two Asian rice subspecies, *Japonica* and *Indica*, which have distinctive tolerance to chilling stress, becomes important for improving crop cold tolerance. Hence, this study hypothesized four potential mechanisms to better understand how *Japonica* can tolerate low temperature exposure better than *Indica*: (1) *Japonica* selectively adjusts antioxidant activities to counter ROS, while *Indica* rapidly increases antioxidant activities early; (2) *Japonica* increases antioxidants to prevent further damage after prolonged exposure, while *Indica* fails to do so due to significant damage; (3) *Japonica* slows water uptake to sustain minimal photosynthesis during cold, while *Indica*'s uptake mechanisms are compromised; (4) Improving cold tolerance in cold sensitive accession via overexpressing *OsUBC7*, a member of the ubiquitination cascade. To answers these aims, this study investigates the enzymatic antioxidant activities and water uptake strategies employed by *Japonica* and *Indica* rice accessions under different cold treatments. Results reveal distinctive strategies in managing reactive oxygen species (ROS) and antioxidant enzyme activities among the subspecies, with *Japonica* showing fluctuating antioxidant activities to potentially activate defense pathways against cold stress, while *Indica* demonstrates rapid but possibly excessive and expensive ROS scavenging responses. Moreover, contrasting water uptake patterns are observed, with *Indica* accessions experiencing significant reductions under cold stress, in contrast to Japonica's more moderate declines, suggesting relative outcomes. Furthermore, this study explores the role of the cold candidate gene *OsUBC7* in cold stress responses and productivity enhancement. Data supports that *OsUBC7* is a significant helper for rice plants to cope with cold stress, with differential expression patterns and single-nucleotide polymorphisms correlating with low-temperature seedling survivability in 370 accessions from both subspecies. Overexpression of *OsUBC7* in cold sensitive accession enhances plant resilience to cold stress by promoting growth rate, increasing sugar metabolism, and increasing chlorophyll content, ultimately contributing to more efficient recovery and higher survivability. Additionally, *OsUBC7* shows potential effects in developmental processes associated with flowering and yield, suggesting promising roles in improving cold stress tolerance and productivity. In conclusion, this doctoral work demonstrates the complex response mechanisms of Asian rice subspecies to chilling stress, emphasizing the importance of ROS perception and management, water uptake strategies, and genetic factors for improving cold stress tolerance. The findings provide valuable insights into the adaptive strategies of Asian rice *Japonica* and *Indica* subspecies, and help develop effective strategies to improve crop cold tolerance in fluctuating environmental conditions.