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Regulation of Flowering, Seed Development, and Germination by microRNAs

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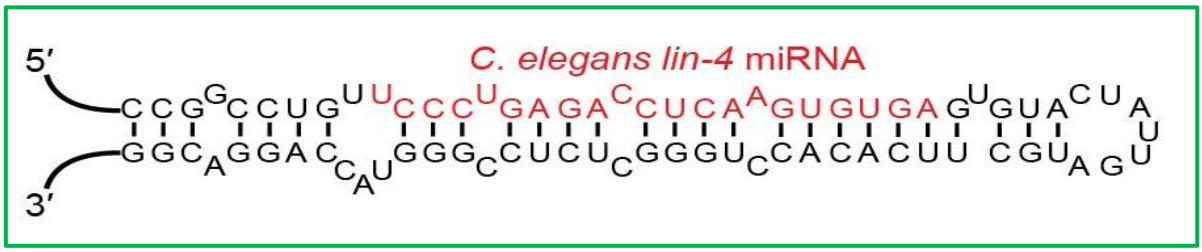
Seed represent a crucial stage of the plants life cycle. Small non-coding RNAs are major regulators of gene expression both at the post-transcriptional and transcriptional levels and these elements play major roles in seed development and germination. As a class of non-coding genes, small non-coding RNAs (ncRNAs) play an essential role in regulating the molecular machinery of eukaryotic cells by controlling transcriptional and post-transcriptional mechanisms. MicroRNAs are a class of endogenous small regulatory ncRNAs with lengths ranging from 20–24 nucleotides (nt) that negatively regulate gene expression at the post-transcriptional level through perfect or near-perfect complementarity with target mRNAs for cleavage or inhibition of translation. Some known miRNA loci form clusters in the genome and these miRNA clusters are probably produced by gene duplication and the miRNAs in a given cluster are often related to one another. MiRNAs are key post transcriptional regulators that control various biological and metabolic processes in eukaryotes, many of which are conserved and have more recently evolved species specific diversity. MicroRNAs also have important regulatory functions in specific biological processes during the life cycle of plants, such as controlling tissue differentiation and development, the phase switch from vegetative to reproductive growth, responses to different biotic and abiotic stresses and regulation of seed development.

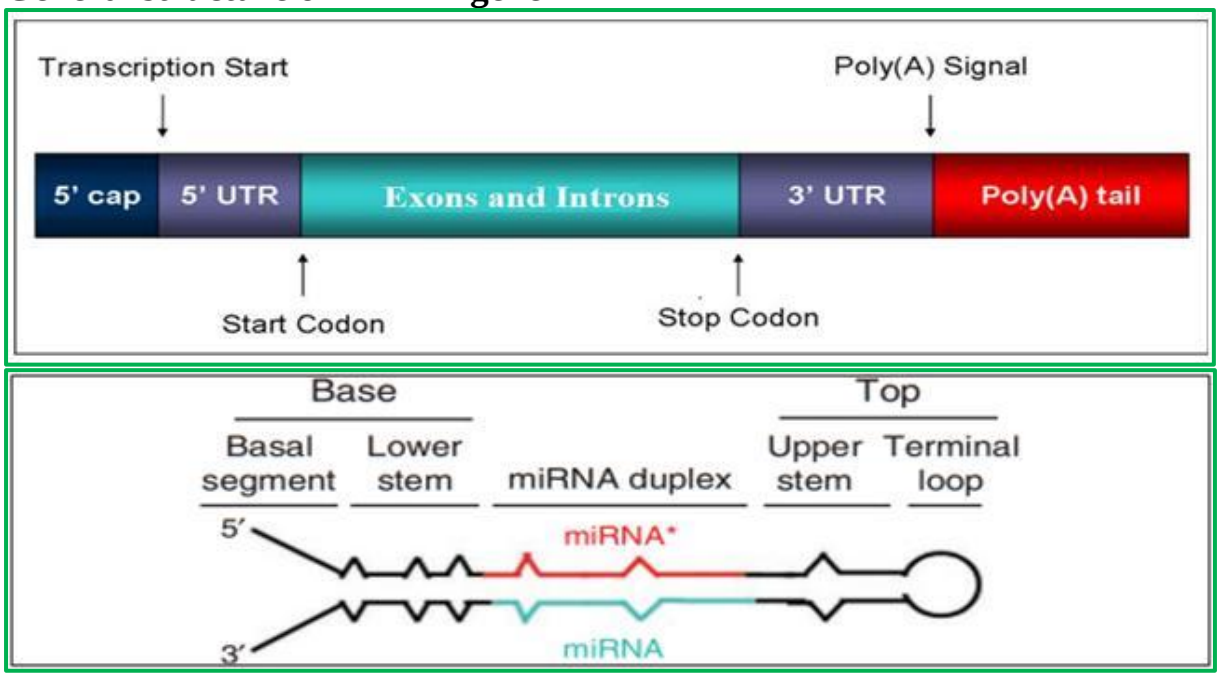
History of microRNAs

- ✓ The first miRNAs were characterized in the early 1990s.
- ✓ MicroRNAs were discovered in 1993 by Victor Ambros, Rosalind Lee and Rhonda Feinbaum during a study of the gene lin-4 in *Caenorhabdadis elegans* development.
- ✓ Therefore, the lin-4 small RNA was the first microRNA to be identified.
- ✓ However, miRNAs were not recognized as a distinct class of biological regulators with conserved functions until the early 2000s.
- ✓ Only in 2000 was a second RNA characterized: let-7, which repressed lin-41, lin-14, lin-28, lin-42, and daf12 expression during developmental stage transitions in *C. elegans*.

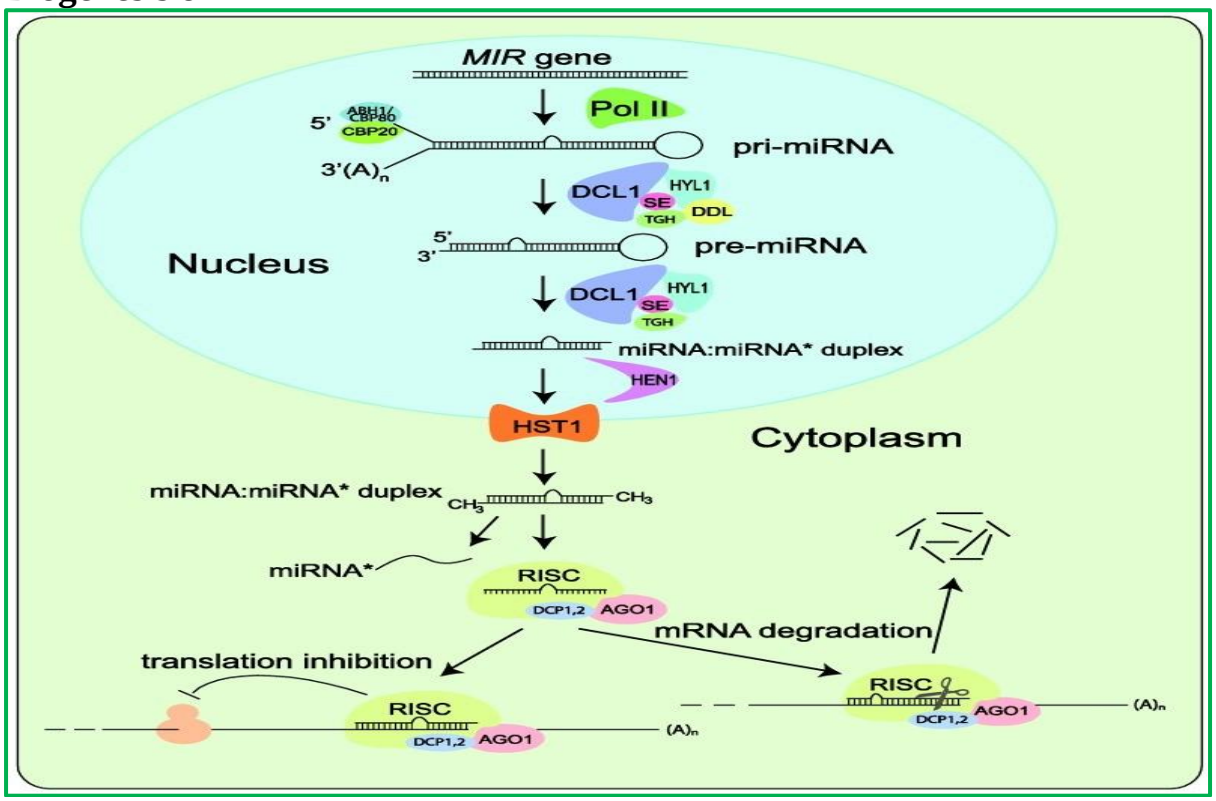
Structure of first microRNA



General structure of miRNA gene



Biogenesis of miRNA



Role of microRNA in plants

1. Involved in biotic and abiotic stress responses in plants.
2. Involved in regulation of seed development
3. Helps promote and delay in plant flowering
4. Regulate seed germination.
5. Regulates genetic male sterility in some species. Eg: wild type cotton.
6. miRNAs trigger formation of mycorrhiza roots and nitrogen-fixing nodules

Functions of miRNAs

In plants, miRNA regulatory functions can be divided into three major categories.

1) miRNAs are capable of defining distinct expression patterns of their targets, in which miRNAs and their targets are expressed on adjoining non overlapping domains.
2) miRNAs prevent variations in the pattern and expression levels of their targets by sharing overlapping expression domains.
3) miRNAs are involved in the temporal regulation of target gene accumulation which regulates developmental transitions.

How does the miRNA function or regulate…?

Control of gene expression by regulating:

1. Transcription factors
2. Stress response proteins
3. Proteins that impact development, growth and physiology of plants

Examples of some role of microRNAs in plants

- miR160: root cap formation in Arabidopsis by targeting ARFs (Auxin Response Factor).
- miR164: Normal lateral root development in Arabidopsis by targeting NAC1.
- miR167: In adventitious rooting by targeting ARFs.
- miR390: Involved in auxin signalling pathways.
- miR393: In anti-bacterial resistance by repressing auxin signalling.
- miR398: Cu/Zn homeostasis.miR399: In response to phosphate starvation.
- miR169: In response to drought
- miR166 and miR169: In controlling nodulation

Conclusion

Seed development is not an exception but rather is a stage that is heavily regulated by miRNAs and their targets and loss of function in miRNA biogenesis, processing and loading associated genes results in embryo lethality, severe embryo defects, or abnormal seedling formation after germination. The timing of expression of individual miRNAs also appears to be important. A specific subset of miRNAs and their targets are involved in embryogenesis, while a different subset of miRNAs may be responsible for seed maturation etc. and miRNAs also play a critical role in the separation of two or more distinct programs in seeds. Future studies are required to unravel the molecular details of small RNAs regulated pathways in seed germination and viability maintenance.

(All Image sources: Google Scholar)