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Coriander Behind the Leaf

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INTRODUCTION

Agriculture today is passing through a critical transition phase. Increasing population pressure, shrinking cultivable land, unpredictable climatic conditions, and frequent abiotic stresses such as drought, heat, salinity, and cold are posing serious challenges to crop production worldwide. Among these stresses, low-temperature or cold stress has emerged as a major constraint affecting the growth, productivity, and quality of many vegetable and spice crops, particularly in temperate, sub-temperate, and hilly regions. Developing crop varieties that can tolerate such stresses has therefore become an important priority for agricultural scientists and plant breeders.Spices occupies a special place in Indian agriculture due to their high economic value, export potential, medicinal importance, and cultural significance. Among them, coriander (*Coriandrum sativum* L.) is one of the most widely grown seed spice and leafy vegetable crops. It is cultivated across diverse agro-climatic zones of India and is valued for its fresh green leaves as well as dry seeds. Coriander leaves are rich in vitamins, minerals, and antioxidants, while the seeds are extensively used as a spice, flavouring agent, and in traditional medicine.

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Despite its importance, coriander is highly sensitive to environmental stresses, especially cold stress during early growth and vegetative stages.Cold stress adversely affects coriander by slowing down seed germination, reducing plant growth, disturbing physiological processes, and ultimately lowering yield. In severe conditions, exposure to low temperature can cause leaf chlorosis, reduced photosynthesis, impaired nutrient uptake, and delayed flowering. For farmers cultivating coriander in northern plains, hilly regions, or during winter seasons, cold stress often results in poor crop establishment and economic losses. Hence, understanding the biological mechanisms that help coriander plants cope with low temperature is essential for developing resilient varieties.

Traditionally, crop improvement for stress tolerance relied mainly on phenotypic selection and conventional breeding. However, these approaches are often slow and limited by the availability of suitable genetic variation. With the advancement of molecular biology, genomics, and bioinformatics, it is now possible to explore plant responses to stress at the gene level. The availability of whole genome sequences has revolutionized our understanding of how plants perceive stress and activate defence mechanisms. Among the various types of genes involved in stress response, a unique and less explored group known as orphan genes has recently gained scientific attention.

Orphan Genes: A New Dimension in Plant Genomics

Orphan genes are genes that do not show any detectable similarity to genes present in other species. In other words, they are species-specific genes that have evolved relatively recently during evolution. Unlike conserved genes that perform basic cellular functions, orphan genes are often associated with specialized traits such as environmental adaptation, stress tolerance, reproductive development, and species-specific characteristics.For a long time, orphan genes were ignored or considered non-functional due to the lack of known homologs. However, recent studies in crops like rice, wheat, *Brassica*, and *Arabidopsis* have clearly demonstrated that orphan genes can play crucial roles in regulating flowering time, sugar metabolism, male fertility, drought tolerance, and cold stress response. These findings suggest that orphan genes act as adaptive tools that enable plants to survive and perform better under challenging environments.In the context of climate change, orphan genes are particularly important because they evolve rapidly and may provide quick adaptive advantages. Studying these genes in economically important crops like coriander can therefore open new avenues for developing climate-resilient varieties.

Genomic Exploration of Coriander

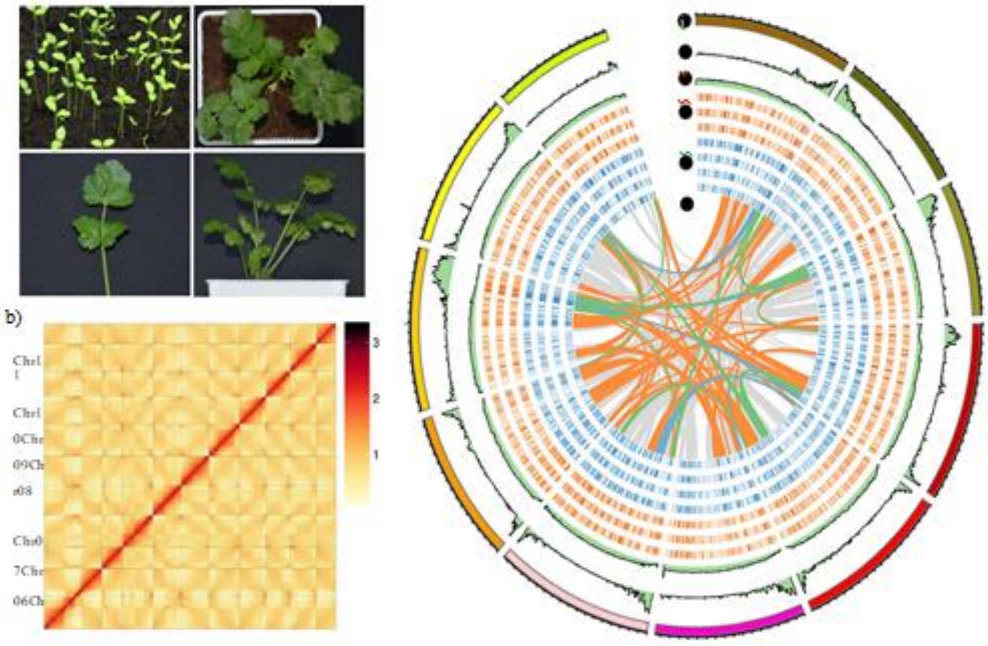
The recent availability of a high-quality genome sequence of coriander has provided a valuable resource for exploring its genetic architecture. Using advanced computational tools and comparative genomics approaches, researchers analysed the entire coriander genome to identify different categories of genes based on their evolutionary origin.

Coriander genes were broadly classified into three groups:

1. Evolutionarily Conserved Genes (ECGs): Genes shared with many other plant species and responsible for basic cellular and metabolic functions.
2. Apiaceae-Specific Genes (ASGs): Genes found only in members of the carrot family (*Apiaceae*), such as coriander, carrot, and celery.
3. Coriander Orphan Genes (CsOGs): Genes unique to coriander that are not found in any other plant species.

Through rigorous genome-wide analysis and comparison with more than 120 plant genomes, researchers identified 941 coriander orphan genes and 1298 *Apiaceae*-specific genes. These genes were distributed across all 11 chromosomes of coriander, indicating that orphan genes are an integral part of the coriander genome rather than rare genetic elements. Structural Characteristics of Coriander Orphan Genes A detailed analysis of gene structure revealed that coriander orphan genes differ significantly from conserved genes. Most orphan genes were found to be shorter in length, contained fewer exons, and had a higher proportion of intron-less genes. Such structural simplicity suggests that these genes may have originated recently through processes like gene duplication, transposable element activity, or de novo gene formation.

The presence of a large number of intron-less genes also indicates rapid evolution, which is a common feature of genes involved in stress responses. These characteristics further support the idea that orphan genes play dynamic roles in helping plants adapt to changing environments.



a) Themorphology, Hi-Cmapand chromosomal features of coriander genomes.(a)The morphology of coriander, including seedlings, top view, front view and leaf. (b) Hi-C map showing genome-wide all-by-all interactions between chromosomes. (c) i, 11 chromosomes of coriander, within 1-Mb windows depicting; ii, gene density; iii, transposable element (TE) content; iv, gene expression levels (Log2FPKM) at 30, 60 and 90days after sowing from outsidetoinside;v,geneexpressionlevels(Log2FPKM)inflower,leaf,rootandstemfromoutsidetoinside; andvi,linesconnectingcolinearblocks; orange,greenandbluecoloursrepresent20–40,40–60and≥60genepairsincolinearblocks,respectively.

Expression of Orphan Genes During Growth and Development

Gene expression analysis provides valuable clues about gene function. To understand when and where coriander orphan genes are active, researchers analysed their expression patterns in different plant tissues such as roots, stems, leaves, and flowers, as well as at different growth stages.The results showed that most orphan genes exhibited low expression levels, which is typical for regulatory and stress-responsive genes. However, several orphan genes displayed tissue-specific expression, particularly in roots and flowers. Roots are the primary organs involved in water and nutrient uptake and are highly sensitive to environmental stress, suggesting that orphan genes expressed in roots may contribute to stress perception and adaptation.Some orphan genes were also found to be active only at specific growth stages, indicating their possible role in developmental regulation. This selective expression pattern highlights the functional importance of orphan genes despite their low overall expression.

Orphan Genes and Cold Stress Tolerance in Coriander

One of the most significant findings of the study was the involvement of coriander orphan genes in cold stress response. To evaluate this, coriander plants were exposed to low temperature (4°C), and the expression of selected orphan genes was monitored.The results were remarkable. Several orphan genes showed a dramatic increase in expression under cold stress, indicating their direct involvement in stress tolerance mechanisms. One particular gene exhibited nearly a 700-fold increase in expression when exposed to cold conditions. Such a strong response clearly suggests that this gene plays a crucial role in helping coriander plants cope with low temperature stress.Cold stress tolerance in plants involves complex mechanisms such as membrane stabilization, antioxidant activity, regulation of stress hormones, and activation of protective proteins. Although the exact molecular functions of these orphan genes are yet to be fully understood, their strong response to cold stress indicates that they may be part of key regulatory pathways.

Agricultural Significance and Future Prospects

The identification of cold-responsive orphan genes in coriander has important implications for agriculture. These genes can serve as valuable genetic resources for developing cold-tolerant coriander varieties through molecular breeding and biotechnology-based approaches. In the future, orphan genes may be used as molecular markers for selecting stress-resilient genotypes at an early stage.For farmers, especially those cultivating coriander in colder regions or during winter seasons, such improved varieties can ensure better crop establishment, stable yields, and reduced risk. From a broader perspective, the study demonstrates how advanced genomic research can contribute directly to sustainable agriculture and climate resilience.

CONCLUSION

Coriander is an economically and nutritionally important crop, but its sensitivity to cold stress limits productivity. The discovery and characterization of coriander-specific orphan genes provide new insights into how plants adapt to low temperature conditions. These unique genes, once overlooked, are now emerging as key players in stress tolerance and crop adaptation.

By bridging the gap between genome-level research and field-level challenges, orphan gene studies offer promising opportunities for future crop improvement. Continued research on the functional validation of these genes will further strengthen their application in developing climate-smart coriander varieties, ultimately benefiting farmers and the agricultural sector as a whole.

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