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Exploring Biotechnological Advancement in Coriander Cultivation: A review

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Abstract

Coriander (*Coriandrum sativum* L.) is an essential herb used widely in culinary, medicinal, and aromatic applications globally. Key developments in coriander improvement including enhances yield, stress tolerance and phytochemical production. The potential of biotechnological approaches in addressing challenges such as disease resistance, environmental stresses and quality improvement is well understood. Genetic modification techniques such as CRISPR/Cas9 have enabled precise gene editing for traits like disease resistance, herbicide tolerance, and improved nutrient uptake. Moreover, biotechnological tools enable precise gene editing, allowing for targeted modifications without introducing foreign genes. This approach ensures the safety and regulatory compliance of genetically modified coriander varieties, addressing concerns related to consumer acceptance and environmental impact. Additionally, advancements in tissue culture protocols have facilitated rapid propagation of elite coriander varieties, circumventing issues related to seed germination and maintaining genetic purity. Molecular breeding strategies employing marker-assisted selection (MAS) and genomic selection have expedited the development of high-yielding coriander cultivars with desirable agronomic traits. “omics” approaches including genomics, transcriptomics, and metabolomics in elucidating the genetic basis of important traits in coriander provide valuable insights into the molecular mechanisms underlying coriander development, stress responses, and secondary metabolite biosynthesis. This review provides an overview of recent biotechnological advancements in coriander research focusing on areas such as genetic engineering, tissue culture, metabolomics, and molecular breeding aimed at enhancing coriander yield, quality, and stress resilience.

Keywords: Coriander, biotechnology, genetic engineering, molecular breeding, protein profiling

Introduction

Coriander (*Coriandrum sativum* L.) also known as dhania or cilantro, chinese parsley is an annual herb with diploid chromosome number ($2n=2x=22$) and belongs to family *Apiaceae*. It is referred to as “kusthumbari” or “dhanayaka” (Prakash, 1990) known for its culinary, medicinal, and aromatic properties. The Egyptians called this herb as “spice of happiness”. It is grown as an important spice crop in India, Morocco, Russia, Turkey and other part of world (Diederichsen, 1996). It is an annual, herbaceous plant which originated from the Mediterranean regions. It is a tropical crop and is cultivated as a summer or winter annual crop according to the climate conditions. Coriander crop requires a cool climate during the growth stage and warm dry climate at maturity. It can be cultivated in most types of soils suits the crop well. Cold climate or high altitudes may lead to superior quality seeds and higher essential oil content. All part of his herb are in use as flavouring agent and treatment of different disorders in the folk medicine systems of different civilization (Sahib *et al.*, 2013). The most important constituents of its seed are the essential oil and fatty oil (Coskuner and Kerabada., 2007).

India is the biggest producer, consumer and exporter of coriander in the world. Madhya pradesh, Gujarat, Rajasthan are the main coriander producing state in the country accounting for 85-90% of production. The largest producer of coriander seed in the country is Rajasthan accounting for about 58% followed by Madhya pradesh with about 15% Assam and Gujarat with 8% each of total domestic coriander seed production. In India, total area under coriander crop is 470 thousand ha with a production of 576 thousand tonnes and productivity of 1231 kg ha⁻¹ during 2021-2022.

In Rajasthan, total area under coriander crop is 70 thousand ha with a production of 78 thousand tonnes and productivity of 1114 kg ha⁻¹ during 2018-2019 (Department of Agricultural, Cooperation and farmer welfare 2021-2022). The highest area for coriander production was reported in district Jhalawar (42%) followed by Baran (35%) and Kota (20%). In Rajasthan, the coriander production was 130.20 tonnes during

2021-2022 (National Horticulture Board). Unfortunately both area and production has declined during recent year due to weather concerns in Rajasthan.

In recent years, biotechnologies has revolutionized agricultural practices, offering innovative solutions to conventional challenges and enhance coriander cultivation, addressing challenges such as yield optimization, disease resistance and quality enhancement. Through genetic engineering, tissue culture techniques, and molecular breeding approaches, researchers can manipulate coriander's genetic makeup to achieve desirable traits. These advancements enable the development of coriander varieties with improved yield, enhanced flavor profiles, and increased resistance to pests and diseases (Gupta *et al.*, 2008). Furthermore, biotechnology facilitates the production of secondary metabolites in coriander, such as essential oils and antioxidants, which contribute to its medicinal and aromatic properties. By understanding the biochemical pathways involved in secondary metabolite synthesis, scientists can manipulate genetic factors to enhance their production, resulting in coriander varieties with increased therapeutic value.

In this paper, we have explored the recent biotechnological advancements in coriander cultivation, including the application of genetic engineering, tissue culture techniques and molecular breeding approaches. We will examine their potential implications for enhancing coriander yield, quality and resilience to biotic and abiotic stresses. Through a comprehensive analysis, we aim to provide insights into the future prospects of biotechnological innovations in sustainable coriander production, contributing to food security and economic development.

Biotechnological approaches: Biotechnological advancements in coriander cultivation have focused on various aspects such as improving yield, enhancing resistance to diseases and pests, and increasing tolerance to environmental stresses like drought or salinity. Techniques like protein profiling, genetic engineering, marker-assisted selection, and tissue culture have been employed to develop coriander

varieties with desired traits such as higher yield, improved flavor, and extended shelf life. Additionally, biotechnological methods have been used to understand the genetic basis of traits in coriander, aiding in the development of more efficient breeding strategies (Figure 1).

Protein profiling: The protein profiling of germplasm and use of genetic markers have been widely and effectively used to determine the taxonomic and evolutionary aspects of coriander. Sodium Dodecyl Sulphate Polyacrylamide Gel Electrophoresis (SDS-PAGE) is the most economical, simple and extensively used biochemical technique for analysis of genetic structure of coriander germplasm. As seed storage proteins are largely independent of environmental fluctuations, there profiling using SDS-PAGE technology is particularly considered as a consistent tool for economic characterization of coriander germplasm (Javid *et al.*, 2004; Iqbal *et al.*, 2005).

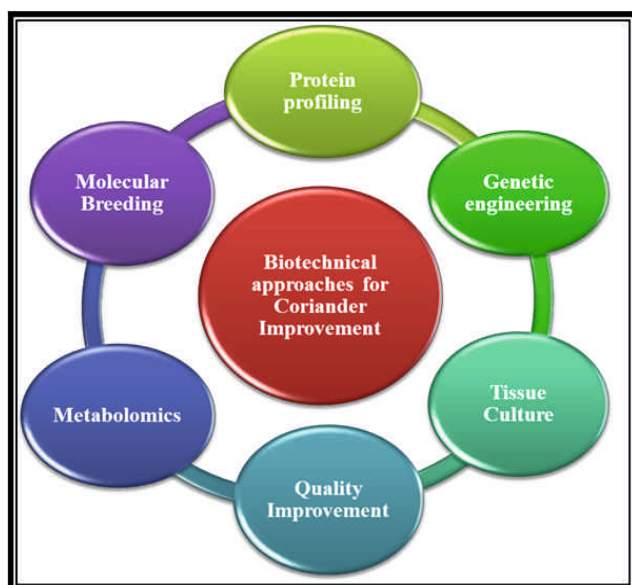


Fig. 1: Biotechnical approaches for Coriander Improvement

Genetic engineering: Through genetic engineering techniques, researchers can manipulate the genetic makeup of coriander plants to enhance their characteristics, leading to more productive and resilient crops. Genetic engineering techniques, including gene editing and genetic transformation, have revolutionized

coriander improvement. Targeted gene editing using CRISPR/Cas9 technology has enabled precise modifications in coriander's genome, enhancing traits such as disease resistance, herbicide tolerance, and essential oil content. Furthermore, transgenic approaches have facilitated the introduction of novel genes for improved yield, flavor, and nutrient composition. This has contributed to the sustainability and profitability of coriander cultivation while addressing challenges such as pest infestations and environmental stresses (Tuteja, 2017; Singh, 2019)(Table 1).

Tissue Culture and Micropropagation : Tissue culture plays a significant role in advancing coriander cultivation through biotechnology by allowing for rapid propagation of elite cultivars, production of disease-free plants, and genetic manipulation for improved traits such as yield, flavor, and resistance to pests and diseases. It also facilitates the preservation of genetic diversity and conservation of rare or endangered coriander varieties. Additionally, tissue culture techniques enable the mass production of uniform plant material with consistent quality, leading to increased productivity and efficiency in coriander farming (Pandey and Nema, 2019; Varshney and Anand, 2019; Rathore *et al.*, 2020).

Molecular Breeding : Molecular marker studies for coriander improvement involve the identification and characterization of genetic markers within the coriander genome. These markers can be used for various purposes such as genetic diversity analysis, marker-assisted selection (MAS) for breeding programs and trait mapping. Common types of molecular markers used in coriander improvement include SSRs (simple sequence repeats), SNPs (single nucleotide polymorphisms), and AFLPs (amplified fragment length polymorphisms). These studies help breeders understand the genetic makeup of coriander populations and facilitate the development of improved varieties with desired traits such as disease resistance, higher yield, and improved flavor. Molecular breeding strategies, including marker-assisted selection (MAS) and genomic selection (GS), have expedited coriander breeding programs. MAS allows for the selection of desired traits at the molecular level, thereby reducing

Table 1. Approaches for advancement in Coriander cultivation for various traits

S. No.	Biotechnological advancement in Coriander	Traits	References
1	Genetic Engineering for Yield Improvement	Introduction of genes for enhanced yield, disease resistance and stress tolerance.	John <i>et al.</i> , 2020
2	Marker-Assisted Selection (MAS)	Utilization of molecular markers to select desired traits, such as aroma or oil content.	Singh, 2018
3	Marker-assisted breeding for disease resistance	Utilization of molecular markers for disease resistance	Narayanan and Sharma, 2019
4	Tissue Culture Techniques	Micropropagation for rapid multiplication of disease-free plants and genetic conservation.	Singh, 2018
5	Genome Editing (CRISPR/Cas9)	Precise modification of specific genes to enhance traits like flavor or shelf life.	Patel <i>et al.</i> , 2021
6	Metabolic Engineering	Modification of metabolic pathways in coriander plants to enhance production of specific compounds, such as essential oils or medicinal compounds.	Dudareva <i>et al.</i> , 2013
7	Protein profiling	Seed storage protein profiling for diversity	Iqbal <i>et al.</i> , 2005
8	Genome sequencing of coriander	Sequencing of expression of various traits	Gupta and Gopala Krishna, 2016
9	Genetic modification for quality	Introduction of genes for enhanced quality	Verma <i>et al.</i> , 2017
10	Development of herbicide - resistant varieties	Development of herbicide -resistant varieties	Gupta and Singh, 2018

the breeding cycle. Similarly, GS integrates genomic information to predict breeding values, enabling the identification of superior genotypes with enhanced traits such as yield, aroma and disease resistance (Gupta *et al.*, 2008; Verma *et al.*, 2015; Mahajan and Gill 2017; Parihar *et al.*, 2016).

Metabolomics and Quality Improvement :

Metabolomic studies have provided insights into the biosynthesis pathways of secondary metabolites in

coriander, including essential oils, flavonoids, and phenolic compounds. Understanding the metabolic profile of coriander facilitates targeted breeding efforts aimed at enhancing its flavor, aroma, and medicinal properties (Table 1).

- 1. Metabolic Profiling:** Metabolomics enables the comprehensive analysis of coriander's metabolic profile, including primary and secondary metabolites, such as sugars, amino acids,

organic acids, and volatile compounds, which influence its nutritional value, flavor, aroma, and medicinal properties (Dudareva *et al.*, 2013).

2. **Trait Improvement:** Metabolomics facilitates the identification of metabolites associated with desirable traits, such as enhanced yield, increased stress tolerance, and improved nutrient content, guiding breeding and genetic engineering efforts for trait improvement (Borghini *et al.*, 2019).
3. **Stress Response Mechanisms:** Metabolomics elucidates the metabolic changes in coriander under various environmental stresses, such as drought, salinity, and pathogen attacks, helping to understand stress response mechanisms and develop stress-tolerant cultivars through targeted manipulation of key metabolites.
4. **Quality Control:** Metabolomics contributes to quality control in coriander production by monitoring the levels of bioactive compounds, contaminants, and adulterants, ensuring the safety, authenticity, and efficacy of coriander-derived products in the pharmaceutical, food, and cosmetic industries (Kumari *et al.*, 2019).
5. **Systems Biology Approach:** Integrating metabolomics data with other omics platforms, such as genomics, transcriptomics, and proteomics, offers a systems biology approach to comprehensively understand the molecular mechanisms underlying coriander physiology and metabolism, facilitating targeted interventions for crop improvement (Alseekh *et al.*, 2020).

Challenges and Future Directions : Despite significant advancements, several challenges persist in the biotechnological improvement of coriander. These include regulatory constraints related to genetically modified organisms (GMOs), limited genomic resources, and genotype-environment interactions. Future research endeavors should focus on overcoming these challenges through collaborative efforts involving biotechnologists, plant breeders, and policymakers. Furthermore, integration of omics technologies, such as genomics, transcriptomics, and

proteomics, holds promise for unraveling the complex biological processes underlying coriander development and stress responses.

Conclusion

In conclusion, biotechnological advancements have revolutionized coriander cultivation by offering innovative tools for genetic improvement, tissue culture, molecular breeding, and quality enhancement. These advancements not only contribute to sustainable coriander production but also address global challenges such as food security and environmental sustainability. Continued research and technological innovation are essential to harness the full potential of biotechnology in meeting the evolving demands of the coriander industry.

Conflict of interest: The authors declare no conflict of interest.

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