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# Advances in Understanding Endogenous Control of Plant Embryogenesis

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**Abstract: -**

*Plant embryogenesis is a critical developmental process in seed plants that ensures the formation of a new organism from a fertilized zygote. This complex process is tightly regulated by a network of endogenous factors, including transcription factors, phytohormones, and small signaling molecules. Recent advances have highlighted the central role of key transcription factors such as LEC1, LEC2, FUS3, and ABI3 in controlling embryo patterning, maturation, and gene expression. In addition, phytohormones like auxin, gibberellins, and abscisic acid play crucial roles in establishing polarity, regulating cell differentiation, and inducing desiccation tolerance. Emerging evidence also emphasizes the importance of peptide growth factors such as phytosulfokine and the inhibitory effects of phenolic compounds in modulating somatic embryogenesis. The interaction between these endogenous components forms a highly coordinated regulatory network that determines embryogenic competence and developmental fate. Despite significant progress, the precise molecular mechanisms underlying these interactions remain partially understood. This review summarizes recent findings on endogenous regulators of plant embryogenesis and highlights their potential applications in plant tissue culture, genetic improvement, and crop biotechnology.*

***Key words**: Plant embryogenesis; Somatic embryogenesis; Zygotic embryogenesis; Transcription factors; Phytohormones; Auxin; Gibberellins (GA); Abscisic acid (ABA); LEC1; LEC2; FUS3; ABI3; Phytosulfokine (PSK); Phenolic compounds; Gene regulation; Plant development etc.*

## Introduction:

Plant embryogenesis is a fundamental developmental process in seed plants that ensures the formation of a new individual from a fertilized egg. This process involves a series of well-coordinated stages, including the establishment of embryo organization,

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accumulation of storage reserves, and acquisition of desiccation tolerance and dormancy (Umehara *et al*., 2007) . The zygote undergoes asymmetric division to produce an apical cell, which forms the embryo proper, and a basal cell, which develops into the suspensor that supports nutrient transfer (West and Harada, 1993) .Due to the inaccessibility of zygotic embryos within maternal tissues, somatic embryogenesis has emerged as a valuable model system. Somatic embryos mimic zygotic embryos in morphology and gene expression patterns, making them a useful tool for studying developmental mechanisms and for applications in plant biotechnology and clonal propagation (Zimmerman, 1993; Williams, 1987) .Plant embryogenesis is regulated by a complex network of endogenous factors, including transcription factors, phytohormones, and small signaling molecules. Understanding these factors is essential for improving plant regeneration systems and crop improvement strategies.

**Transcription Factors in Embryogenesis**

Transcription factors play a central role in regulating gene expression during embryogenesis. Four key regulators—LEC1, LEC2, FUS3, and ABI3—have been identified from embryo-defective mutants and are crucial for both zygotic and somatic embryogenesis (Baumbusch, 2006) .

**LEAFY COTYLEDON1 (LEC1)**

LEC1 encodes a subunit of the CCAAT-binding transcription factor and is specifically expressed during seed development. It is essential for proper embryo formation, as mutations result in abnormal cotyledon development and reduced storage protein accumulation (Lotan *et al*., 1998; Vicient *et al*., 2000) . Moreover, ectopic expression of LEC1 can induce somatic embryo formation in vegetative tissues.

**LEAFY COTYLEDON2 (LEC2)**

LEC2 is closely related to FUS3 and acts upstream in regulatory pathways controlling embryogenesis. It induces somatic embryo formation and regulates the expression of other transcription factors such as ABI3 and FUS3 (Stone *et al*., 2001; To et al., 2006)

**FUSCA3 (FUS3)**

FUS3 regulates late embryogenesis and seed maturation. It influences the accumulation of storage proteins and controls gene expression through binding to conserved promoter elements (Bäumlein *et al*., 1994; Kroj *et al*., 2003) . Mutations in FUS3 lead to abnormal embryo development and altered metabolic profiles.

**ABA-Insensitive3 (ABI3)**

ABI3 plays a crucial role in abscisic acid (ABA)-mediated gene expression during late embryogenesis. It regulates seed maturation processes, including desiccation tolerance and dormancy, by controlling LEA (Late Embryogenesis Abundant) protein expression (Parcy *et al.*, 1994) .Collectively, these transcription factors form a regulatory network that integrates hormonal signals and developmental cues to ensure proper embryo development.

**Role of Phytohormones**

Phytohormones are key regulators of embryogenesis, influencing cell division, differentiation, and developmental patterning.

**Auxin**

Auxin plays a pivotal role in establishing embryo polarity and axis formation. Polar auxin transport, mediated by PIN proteins, determines the spatial distribution of auxin within the embryo (Friml *et al.*, 2003) . Disruption of auxin transport results in abnormal embryo morphology, highlighting its importance in early development.

**Gibberellins (GA)**

Gibberellins are involved in embryo growth and axis elongation. While GA promotes normal development of the embryo, it may inhibit somatic embryogenesis by maintaining cells in a non-embryogenic state (Tokuji *et al.*, 2003; Mitsuhashi *et al.*, 2003) . Transcription factors such as LEC2 and FUS3 negatively regulate GA biosynthesis, indicating a balance between growth and differentiation.

**Abscisic Acid (ABA)**

ABA is primarily associated with late embryogenesis, particularly in inducing desiccation tolerance and seed dormancy. Although it is not essential for early embryo formation, ABA influences somatic embryogenesis by enhancing embryogenic competence under stress conditions (Kikuchi *et al.*, 2006) . The interaction between ABA and GA suggests a competitive regulatory mechanism in determining cell fate.

**Other Regulatory Molecules**

**Phytosulfokine (PSK)**

PSK is a peptide growth factor that promotes cell division and somatic embryogenesis. It acts through specific receptors and enhances embryogenic cell proliferation in various plant species (Matsubayashi and Sakagami, 1996; Kobayashi *et al.*, 1999) .

**Phenolic Compounds**

Certain phenolic compounds act as inhibitors of embryogenesis. For example, 4-hydroxybenzyl alcohol (4HBA) suppresses somatic embryo formation by inhibiting cell division at early stages (Kobayashi *et al.*, 2000a) . Similarly, compounds like vanillyl benzyl ether (VBE) and 4PMP accumulate in culture media and negatively affect embryogenesis, especially under high cell density conditions.

## Conclusion

Plant embryogenesis is a highly regulated and complex process controlled by an interplay of transcription factors, phytohormones, and signaling molecules. Key transcription factors such as LEC1, LEC2, FUS3, and ABI3 coordinate developmental programs, while hormones like auxin, GA, and ABA modulate growth and differentiation. Additionally, small molecules such as PSK and phenolic compounds further influence embryogenic outcomes.

Despite significant advances, many aspects of embryogenesis remain unclear, particularly the integration of hormonal signaling with genetic and epigenetic regulation. Future research focusing on molecular interactions and epigenetic modifications will provide deeper insights into embryogenesis and enhance its application in plant biotechnology and crop improvement.

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