

Molecular approaches in crop growth regulators

Chongtham Allaylay Devi and Brij Bihari Pandey

Corresponding author email: chongthamallaylaydevi@gmail.com

Introduction

A plant growth regulator is an organic compound, either natural or synthetic, that modifies or controls one or more specific physiological processes within a plant. If the compound is produced within the plant it is called a plant hormone.

A plant regulator is defined by the Environmental Protection Agency as "any substance or mixture of substances intended, through physiological action, to accelerate or retard the rate of growth or maturation, or otherwise alter the behaviour of plants or their produce.

Additionally, plant regulators are characterized by their low rates of application; high application rates of the same compounds often are considered herbicidal". Changes can also be made through the modern methods of genetic engineering.

Molecular regulators of plant growth

Plants and animals have different developmental strategies for growth yet individuals of both attain characteristic species-specific sizes constrained by their developmental genetic programmes. Additionally, growth can be significantly influenced by environmental factors specifically so in plants. However, understanding how plant growth is regulated at the molecular level and through which molecular mechanisms environmental signals are able to influence growth has become the main emphasis in future aspect.

The key factor in growth is the duration of cell proliferation and the timing of the exit from proliferation to cell expansion and differentiation. In plants cell proliferation is largely concentrated in specialised regions known as meristems, which contain the stem cells. In meristems undifferentiated cells are produced by cell proliferation, and when these cells stop dividing, as they leave the meristematic region they differentiate into specific tissues. During differentiation, plant cells frequently increase their DNA content by a modified mitotic cycle called endo-reduplication, a process of continuous DNA synthesis without intervening mitosis.

Molecular Mechanism for regulation of genes

- ✓ The molecular mechanisms which maintain stem cell activity in the meristems, control the balance between cell division and differentiation and switch from mitotic cell cycle to endoreplication during organ development.
- ✓ Genes involved in the regulatory mechanisms make the decision to enter or leave the division cycle.
- ✓ Genes from the model plants *Arabidopsis thaliana* called E2F transcription factors, is to regulate cell cycle entry, but it is becoming apparent in many systems that E2Fs have broader functions.
- ✓ Besides the regulation of cell cycle transitions, they coordinate cell proliferation with cell growth and differentiation.
- ✓ The current model is that E2Fs can work both as positive and negative regulator of transcription, depend on their structure and on the function of the retinoblastoma (RB) tumour suppressor protein. Post-embryonic growth in plants depends on the continuous supply of undifferentiated cells within meristems.

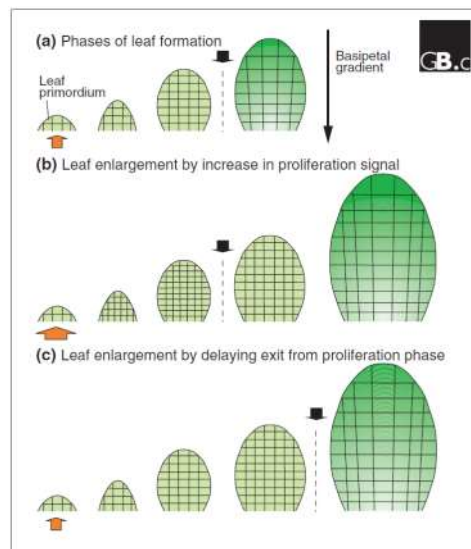


Figure: Mechanisms for organ size control.

- (a) Organ formation, exemplified here by leaf development, consist of two stages.
- i. The first phase is underpinned by cell proliferation, characterized by intense macromolecular/cytoplasmic synthesis and rapid cell division.
 - ii. The second phase is characterized by cell expansion and differentiation. Differentiation takes place along basipetal gradient (that is, from leaf tip to leaf base), as indicated here by the gradient in cell size and cell greening. The red arrow summarizes the proliferative inputs, and the black arrow the arrest of proliferation and initiation of differentiation.

(b) Increasing proliferation signals or

(c) Delaying the transition between proliferation and differentiation. In both cases the number of cells available for organ formation at the end of the proliferative phase is increased, but the underlying mechanisms are different.

- ✓ The maintenance of stem cells in the plant meristems is crucial for the growing plants.
- ✓ Recently, found that ectopic co-expression of E2FB and DPA heterodimeric transcription factors increases the amount of stem cells in Arabidopsis roots which further supports the involvement of the plant RBR-E2F pathway in the regulation of stem cell maintenance.

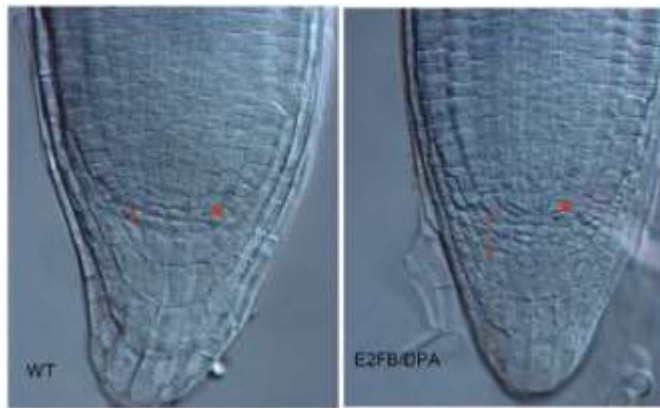


Figure: Ectopic co-expression of E2FB with DPA increases the amount of stem cells in the root meristem of Arabidopsis as indicated by red arrow. Position of the quiescent centre (QC) is indicated.

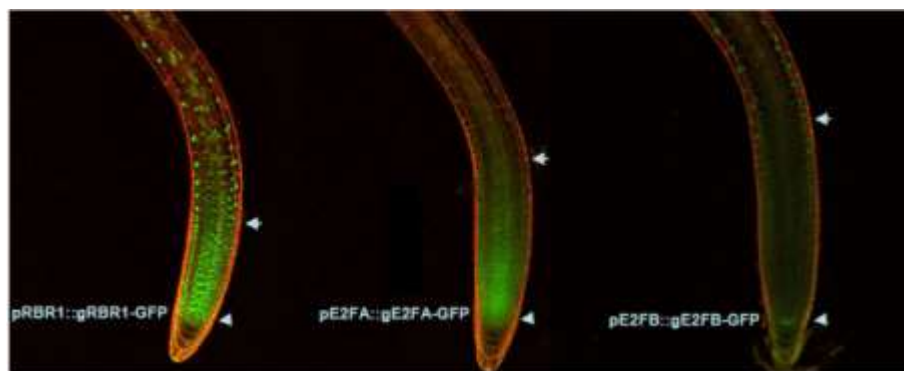


Figure: E2FA and E2FB could regulate different processes by making complex with RBR1 in tissue specific manner.

(A) E2FA and E2FB proteins show opposite expression pattern in the root meristem: E2FA-GFP signal is

the strongest in dividing cells, while E2FB-GFP becomes more abundant in post mitotic cells. RBR-GFP protein shows ubiquitous expression. Arrows show the distal end of the meristem, arrowheads indicate the position of the quiescent centre.

(B) Proposed working model for E2FA and E2FB function when they form complexes with RBR1.

Molecular approaches of Auxin

- ✓ The plant hormone auxin is thought to be involved in diverse growth and developmental processes.
- ✓ The mechanisms by which the hormone exerts its effects are unknown.
- ✓ Recent evidence suggests that auxin can rapidly and specifically alter the expression of a select set of mRNAs.
- ✓ Auxin-responsive mRNAs from several plant systems have been isolated and characterized and, in a few cases, the corresponding gene sequence and organization have been elucidated.
- ✓ The rapid accumulation of auxin-responsive mRNAs appears to be regulated at both the transcriptional and post-transcriptional levels.
- ✓ Research efforts are currently focused on elucidating the cis-acting elements and trans-acting factors that mediate the regulation of genes by auxin.
- ✓ Additionally, the function of the auxin-responsive gene products and their relationship, if any, to auxin-regulated growth processes remain to be determined.

Early Genes and Auxin Action

- ✓ The paradigm of early genes induced by IAA is a viable concept from which to elucidate molecular mechanisms of auxin action.
- ✓ As primary genes identified in animal systems, early-auxin-inducible gene products appear to play important roles in emergency rescue and stress adaptation, intercellular communication, and regulation of late gene expression.
- ✓ However, a causal role of any Auxin responsive gene in cellular physiology and regulation of secondary-phase gene expression remains to be established, and wish to have have Early Genes in Auxin Action.
- ✓ The construction of mutant plants, preferably knock-outs defective in the expression of those genes, is imperative.
- ✓ The stage has been set with the isolation of homologous mRNAs and parental genes from *A. thaliana*, a plant species of choice for reverse genetics.
- ✓ Identification of the regulatory targets of Aux/IAA proteins bears the potential to link

mechanisms of auxin perception and stimulus transduction to auxin-induced biochemical and physiological processes responsible for plant cell growth, such as cell cycle control, cell turgor regulation, secretion, or cell-wall biosynthesis.

- ✓ More importantly, Auxin specific expression of early genes, mediated by characterized *AuxXEs*, provides a long-sought specific molecular phenotype to design genetic screens for mutants defective in auxin signal transduction.
- ✓ Such reverse genetic screens aim at the processing machinery upstream of early gene activation.
- ✓ Molecular Aspects of Seed Dormancy
- ✓ Seed dormancy provides a mechanism for plants to delay germination until conditions are optimal for survival of the next generation.
- ✓ Dormancy release is regulated by a combination of environmental and endogenous signals with both synergistic and competing effects.
- ✓ Molecular studies of dormancy have correlated changes in transcriptomes, proteomes, and hormone levels with dormancy states ranging from deep primary or secondary dormancy to varying degrees of release.
- ✓ The balance of abscisic acid (ABA), gibberellin (GA) levels and sensitivity is a major, but not the sole, regulator of dormancy status.
- ✓ ABA promotes dormancy induction and maintenance, whereas GA promotes progression from release through germination; environmental signals regulate this balance by modifying the expression of biosynthetic and catabolic enzymes.
- ✓ Mediators of environmental and hormonal response include both positive and negative regulators, many of which are feedback-regulated to enhance or attenuate the response.

Molecular mechanism of gibberellin signalling in plants

- ✓ The hormone gibberellin (GA) plays an important role in modulating diverse processes throughout plant development.
- ✓ In recent years, significant progress has been made in the identification of upstream GA signaling components and trans and cis-acting factors that regulate downstream GA-responsive genes in higher plants.
- ✓ GA appears to derepress its signaling pathway by inducing proteolysis of GA signaling repressors (the DELLA proteins).
- ✓ DELLA proteins are targeted for degradation by an E3 ubiquitin ligase SCF complex through the ubiquitin-26S proteasome pathway.
- ✓ The newly available whole genome expression profiling and proteomic technology will be

additional powerful tools to facilitate the identification of the GA receptor(s), new GA signaling components, and tissue-specific GA-regulated genes.

GA-Response Mutants

- ✓ GA responses to mutants with altered stem heights in a variety of species have been isolated
- ✓ Mutants with constitutively active GA responses have a slender and paler-green phenotype, which mimics wild-type plants that are overdosed with GA.
- ✓ Mutants that are impaired in the GA signaling resemble the GA biosynthesis mutants, i.e., dark-green dwarf with compact leaves, and some with reduced fertility.
- ✓ But their phenotype cannot be rescued by GA treatment.

Molecular Approach to Plant Growth Regulation by Constitutive Over expression of *Nicotiana* GA_2ox in *Kalanchoe blossfeldiana*

- ✓ The development of an alternative method to chemical treatment for growth retardation in crop and ornamental plant production has become a top target in recent breeding programs.
- ✓ The present work describes the phenotypes of transgenic *Kalanchoe blossfeldiana* plants with overexpressed *gibberellin 2-oxidase* (GA_2ox) from *Nicotiana tabacum* under the 35S promoter.
- ✓ The height of the transgenic *Kalanchoe* lines was reduced by a factor of almost 2 in comparison to the control plants, while the number of nodes was similar between the transgenic and control plants.
- ✓ The height of the inflorescence stem of the transgenic lines was approximately three times reduced. However, the transgenic clones exhibited a delay in flowering that amounted to approximately 24 days.
- ✓ The flower morphology for all of the investigated transgenic lines was the same as that for the control plants. The transgenic lines had visibly darker leaves containing approximately two times as much chlorophyll as the leaves of the control plants.
- ✓ These results demonstrate that the overexpression of GA_2ox may become a useful method for obtaining compact growth of horticultural species without the use of chemical growth retardants.

Molecular approaches for enhancing sweetness in fruits

- ✓ The quality of fruits is mainly dependant on the sweetness determined by the level of soluble sugars such as glucose, fructose and sucrose.
- ✓ Total sugar content in fruits and vegetables is a function of genetic, nutritional, environmental and developmental factors.
- ✓ Understanding the factors controlling sweetness is important to design strategies for enhancing

quality of fruits and vegetables.

- ✓ Modifying the activity of enzymes in carbohydrate metabolism such as sucrose synthase (SuSy), acid invertase, ADP-glucose pyrophosphorylase (AGPase), sucrose phosphate synthase (SPS) and sucrose transporters were found to influence carbohydrate partitioning and sucrose accumulation in sink tissues of several food crops.
- ✓ Plant based taste-modifying sweet proteins such as brazzein, cucurmin, mabinlin, monellin, miraculin, neoculin and thaumatin have potential application for developing transgenic plants to improve the sweetness and quality of fruits.

Molecular regulation of fruit ripening

Fruit ripening is a highly coordinated developmental process that coincides with seed maturation.

The ripening process is regulated by thousands of genes that control progressive softening and/or lignification of pericarp layers, accumulation of sugars, acids, pigments, and release of volatiles.

In tomato, mutations blocking the transition to ripe fruits have provided insights into the role of ethylene and its associated molecular networks involved in the control of ripening.

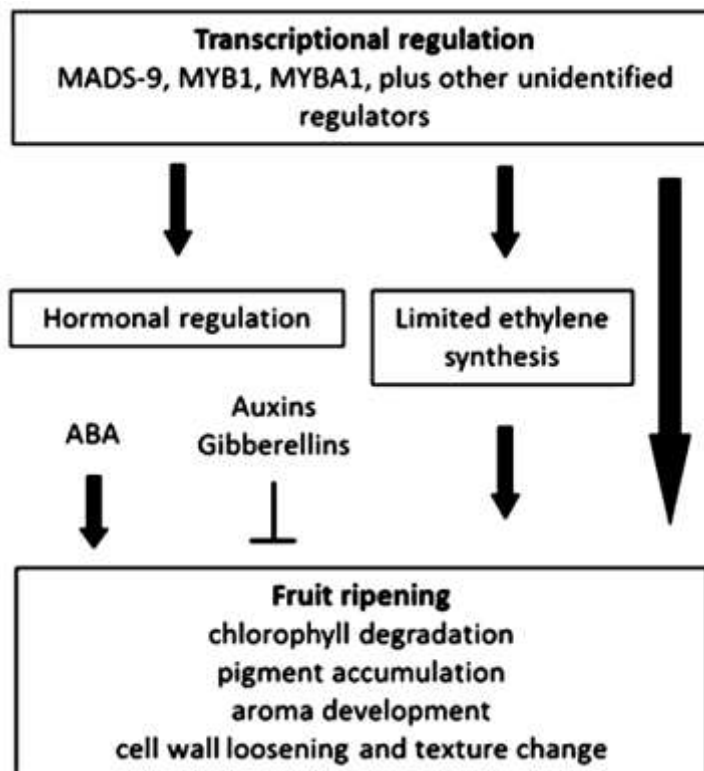


Figure: Overview of ripening regulation in non-climacteric fruits

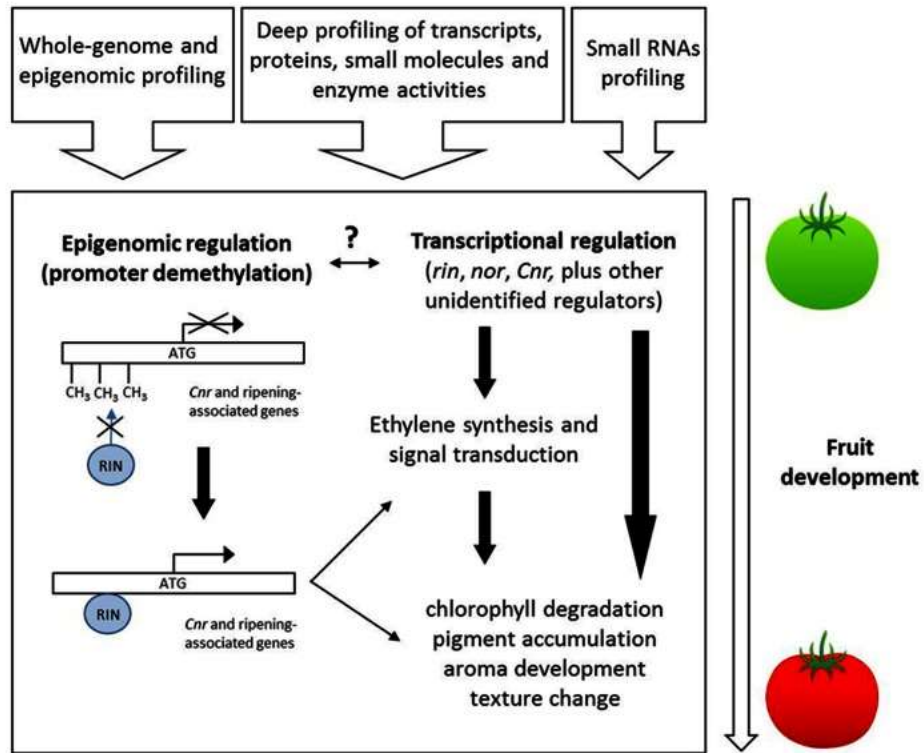


Figure: Overview of ripening regulation in climacteric fruits.

References (if any)

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