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Manipulating the Ripening Process in Fruits through Plant Growth Regulators

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Phytohormones, also known as plant growth regulators, are organic compounds that higher plants naturally create. They are active in trace levels and regulate physiological processes, including growth, at a location away from the site of synthesis. Thimmann coined the term "phytohormone" since plants produce these hormones. Auxins, gibberellins, cytokinins, ethylene, growth retardants, and growth inhibitors are examples of plant growth regulators.

A number of metabolic pathways are involved in a series of processes that convert an advanced green fruit into a ripe fruit in a constrained amount of time. A number of regulatory processes must work together for fruit ripening, which alters the physiological and metabolic characteristics of ripening fruits. Fruit ripening results in various pigments accumulating, complex carbohydrates being converted to sugars, a decrease in fruit acidity as sugars build up, the accumulation of flavor and aroma compounds, and changes in cell wall dynamics that either cause a dehiscence or a softening of the fruit. While other plant regulators contribute to the ripening process of fruit, ethylene and ABA are the primary regulators of ripening. Ethylene and indole-3-acetic acid (IAA) interact with one another throughout the ripening process in climacteric fruits. Ethylene and indole-3-acetic acid (IAA) interact with one another throughout the ripening process in climacteric fruits. Auxin's role in this crosstalk appears to be complex: first, high auxin concentration in the early stages of ripening is primarily ascribed to high hormone levels in seeds, since auxin is either very low or nonexistent in pericarp or locular tissue; second, ripening-associated GH3 genes are thought to lower the free IAA concentration, and this may be the reason for the low auxin levels in the remaining fruit tissues. Furthermore, in strawberry seed tissues with high auxin levels, there was an up-regulation of numerous GH3 genes, such as GH3.1, GH3.5, GH3.9, and GH3.17, suggesting that even IAA production may cause IAA conjugation by enhancing the expression of others members of this gene family.

Since there is no ethylene production spike in non-climacteric fruits, ABA plays a bigger role in ripening. It has been observed that any therapy that impedes the increase in ABA content that occurs during ripening in fleshy fruits would also impede the induction of ripening. The greatest ABA level in tomato and peach fruits occurs before the climacteric ethylene production. By upregulating the genes responsible for ethylene production, ABA accelerates ripening. Similarly, simultaneous elevation of ABA in developing siliques has been associated with ethylene-mediated dehiscence promotion in Arabidopsis. Apart from ABA, GA has been shown to postpone the ripening of numerous other fruits, including tomatoes, peaches, mangos, sapotas, and so on. In addition to these hormones, methyl jasmonate's endogenous level (MJ) has been found to increase with the progression of ripening in apple, mangoes, pears and tomatoes.

Relative roles of hormones fruit color and pigmentation

Fruit color changes during ripening are caused by the formation of color metabolites such anthocyanin and carotenoids as well as the breakdown of chlorophyll, or "de-greening." A number of carotenoid pathway genes, including PSY1, which encourages the synthesis of secondary metabolites responsible for a range of colors, are induced by ethylene. Additionally, ethylene biosynthesis-related genes like LeACS2 and signaling genes SlAP2a and SlERF6 can be altered, which might impact tomato fruit color. This process is accelerated by ethylene. Similarly, ethylene is necessary for the proper degreening of citrus and melon fruit skin. In addition to ethylene, it has also been discovered that a rise in ABA is connected to a change in fruit color. A reduced amount of ABA is present in tomato over-pigmentation mutants such higher pigment3 (hp3), flacca (flc), and sitiens (sit). Higher amounts of lycopene and β-carotene accumulation in transgenic tomato fruits with silenced SlNCED1 further corroborate this observation. Moreover, ABA has been connected to strawberry and grape color changes. Application of 1-methylcyclopropene, an inhibitor of ethylene responses, was observed to delay the ABA action related to color change, suggesting that ethylene is necessary for this process. Furthermore, studies have demonstrated the detrimental effects of NO in apple, longan, and banana fruits as well as the beneficial effects of other phytohormones such GA in banana and kakis fruits, BRs in tomato, grape, and strawberry fruits, and jasmonic acid (JA) in tomato and strawberry fruits.

Relative roles of hormones cell wall dynamics and fruit softening

Combinatorial action of ethylene, ABA, and JA in the dry fruits of Arabidopsis involves the modulation of genes producing cell wall hydrolysis enzymes, such polygalacturonase (PG), in order to promote correct floral organ abscission. In transgenic strawberry plants, the inhibition of PG1 or pectate lyase expressing genes resulted in changed pectin solubility and prolonged fruit firmness during ripening. It has been discovered that auxin regulates the fine pectin structure and tissue architecture in tomatoes through SlARF4. In addition, ABA controls the firmness of tomato fruit and encourages softening by working in concert with ethylene in banana fruit. In a number of fruit crops, including tomato, peach, banana, and sapota, NO helps to soften the fruit.

Relative roles of hormones in accumulation of sugars

When ABA is applied exogenously to grapes during the veraison stage, more metabolites, including sugars, accumulate. Tomato fruit quality is regulated by a gene called SlAREB1, which encodes an ABA response element binding factor. When compared to antisense suppression lines, tomato fruits over-expressing the SlAREB1 gene acquire a greater concentration of several metabolites, including citric acid, malic acid, glutamic acid, glucose, and fructose, throughout the red ripe stage. This suggests that ABA regulates fruit quality. Moreover, ABA helps to promote the hydrolysis of starch in melon. Mango fruit starch breakdown has also been observed to be postponed by GA treatment.

Relative roles of plant hormones in flavour and aroma production

Alcohol dehydrogenases (ADH) are favorably regulated by ethylene in melon fruits, as evidenced by the decreased ADH activity observed in melon fruits treated with 1-MCP and transgenic fruits expressing the ACC oxidase gene repressed. When exogenous ethylene is present, transgenic apple fruits with low endogenous ethylene levels produce more volatile compounds. Apples produce scent in response to jasmonates through the action of ethylene. The control of flavonoid production in highbush blueberries is mediated by ABA. Moreover, transgenic tomato lines with significantly decreased MJ levels accumulate less polyamines in their fruits, suggesting that intracellular MJ plays a crucial role in controlling primary metabolism in general, particularly the regulation of amino acids and polyamines.

References

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