International Journal of Multidisciplinary Research and Growth Evaluation.

Research progress on physiological differentiation and mechanism of citrus flower buds

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Article Info

ISSN (online): 2582-7138
Volume: 06
Issue: 02
March-April 2025
Received: 09-01-2025
Accepted: 10-02-2025
Page No: 12-14

Abstract
Flower bud physiological differentiation is the key transition from vegetative growth to reproductive growth, which includes physiological and biochemical changes, transcriptional regulation, epigenetic modification, protein modification and signal transduction. The flower formation of citrus refers to the process of its axillary buds gradually transforming into flower buds. To understand this process deeply is of great significance for mastering the phenological law of citrus, accurately regulating its flowering time, off-season cultivation and breeding of new varieties. In this paper, the physiological differentiation process of citrus flower bud was systematically reviewed, and the regulation effects of internal and external factors on this process were discussed, as well as the recent progress of related genes involved in regulation. In addition, the regulation map of citrus flower formation pathway is also drawn to show the complex regulatory network in an intuitive form. Finally, the future trend and direction of citrus flower bud differentiation research were prospected in order to provide reference for related research.

DOI: https://doi.org/10.54660/.IJMRGE.2025.6.2.12-14

Keywords: Citrus, Flower bud, Physiological differentiation

1. Introduction

In the global fruit market, citrus has become the favorite fruit of many consumers with its unique taste and rich nutritional value [1]. However, there are also some problems hidden behind the prosperity of the citrus industry. One of the main problems is that the market time of citrus fruit is too concentrated, which limits its value to some extent. With the progress of science and technology, scientists began to realize that by regulating the flowering period of citrus, the ripening time of its fruits can be effectively adjusted, so as to realize the out-of-season listing and improve the economic value of citrus [2]. By regulating the flowering period of citrus, we can not only improve the yield and market value of citrus, but also enrich its ornamental value and add more colors to landscaping. Citrus flowering is not concentrated in spring or difficult to form flowers, which is easy to lead to the annual flowering of the tree, resulting in low fruit rate and poor quality of citrus, and waste of tree nutrition [3].

Flower bud differentiation of citrus is a complex and interesting process. In the initial stage of differentiation, vegetative bud and reproductive bud are difficult to distinguish in appearance, and they will differentiate into corresponding reproductive bud or vegetative bud according to the induction of external environmental conditions. There are many factors affecting this physiological differentiation process, mainly including internal factors, external factors and other factors. Internal factors include tree age, amount of fruit, nutritional status, endogenous hormone level, etc., while external factors include horticultural management measures such as temperature, soil moisture content, and ring cutting. All these influencing factors affect the physiological differentiation of flower buds by affecting the expression levels of functional genes and transcription factors in the flower bud differentiation pathway of citrus. Through in-depth study of the mechanism of citrus flower bud differentiation, we can more accurately regulate the flowering time of citrus, realize the wrong season market, and improve the economic value and ornamental value of citrus.

2. Physiological differentiation of citrus flower buds

Most of the citrus axillary buds are mixed buds, which undergo different differentiation induction processes and eventually form flower buds or leaf buds. Physiological differentiation of citrus flower buds usually begins after shoots stop growing and mature, while morphological differentiation follows. The physiological differentiation of citrus flower buds can be divided into three stages: induction, arousal and initiation. In the induction stage, the physiological differentiation process of citrus flower buds is closely related to nutrients and genetic material [4]. In the induction stage, axillary buds with higher C/N ratio and sugar content are more likely to differentiate into flower buds, while axillary buds with lower C/N ratio and sugar content are more likely to form leaf buds. Flower bud arousal is a process of accumulation of flower forming factors after flower bud induction, and this process is unidirectional. Once flower bud arousal is completed, the transformation to flower bud will be irreversible. The induction and arousal stages of citrus have a high demand for water and nutrients, which determine the timing and quality of flower bud physiological differentiation [5]. As time goes by, with the temperature dropping in autumn, the activity rate inside flower buds begins to decline, and nutrient accumulation continues in winter. Flower bud initiation is a process in which the apex meristem develops into flower after the bud axis completes the physiological and biochemical transformation, which marks the transition from vegetative growth to reproductive growth. It is worth noting that the axillary buds formed in the autumn of the previous year will first enter the physiological differentiation of flower buds compared with the axillary buds in spring and summer. It can be seen that the physiological differentiation process of citrus flower buds is complicated and is restricted by many factors.

3. Factors influencing physiological differentiation of citrus flower buds

Relevant studies on citrus with different tree ages found that with the growth of citrus planting years, the nutrient absorption capacity of the tree gradually weakens, such as the fruit quality and size of Changshan Orange grapefruit will decrease with the increase of tree age [6]. To some extent, these conditions can indirectly reflect the influence of tree age on the physiological differentiation of citrus flower buds, but there are few relevant studies, and further studies need to be carried out. Flowers and fruits in citrus interact with each other. Flowering consumes a lot of nutrients, leading to a decrease in the content of elements such as B and Ca, which restricts the quality of fruits, and a larger fruit yield will negatively affect the amount of citrus flowers in the next year [7].

During the growth of citrus, various abiotic stresses, including temperature stress and water stress, are often encountered, which can cause changes in the expression levels of flowering related genes in citrus, thus affecting its flowering. Temperature is a key environmental factor affecting plant growth and development, especially low temperature stress, which is very important for the vernalization process of plants. Studies have shown that low temperature stress can promote the expression of *FLC*, a positive regulatory gene for flower bud differentiation, and thus promote flowering [8]. 30 days of moderate water stress can increase the expression levels of *FT* and *AP1* of flowering genes, thus promoting the physiological differentiation of flower buds. In the study of lemons, it was found that the flower amount of lemons without water stress was less, and after a period of water stress, although the vegetative growth of lemons was inhibited, its flower amount increased significantly. The mechanism may be that water stress promotes the accumulation of ABA in lemons, and the increase of ABA will accelerate the accumulation of carbohydrates, CTK, starch and other substances, while inhibiting the synthesis of GA, thus promoting floweringsss [9].

4. Molecular mechanism of physiological differentiation of citrus flower buds

In the study of flowering mechanism of plants, Arabidopsis thaliana, as a model plant, has been relatively mature. In Arabidopsis Thaliana, FLOWERING LOCUS T (FT) and TERMINAL FLOWER 1 (TFL) showed a competitive relationship in flowering regulation. In addition, MOTHER OF FT AND TFL1 (MFT) in the PEBF gene family is considered to be the upstream gene of FT and TFL, while TF-like (TSF) is closely related to FT and TFL. In addition, BROTHER OF FT AND TFL (BFT) and CEN genes are also related to FT and TFL [10].

The process of flower formation in plants is a complex biological phenomenon, which involves many regulatory pathways. At present, the more clearly studied flower formation regulation pathways mainly include photcyclic pathway, gibberellin (GA) pathway, autonomic pathway and vernalization pathway. These four pathways influence each other and coordinate with each other in the process of citrus flowering, which together constitute a complex and interconnected flower bud differentiation regulation network. In-depth analysis of these regulatory pathways and their interactions will provide an important theoretical basis and practical guidance for shortening the production time and increasing the amount of flowers.

5. Conclusion

With the deepening of the research on citrus flower formation, the mechanism of citrus flower bud differentiation is gradually improved. It is of great significance to analyze the physiological differentiation of citrus flower buds and explore the technology of promoting flower cultivation in combination with the molecular mechanism to shorten the flowering stage, regulate the flowering time and flowering quantity of citrus. With the further study of citrus related flowering genes, the floral regulation network can be constructed preliminarily. On this basis, the use of transgenic technology to breed early flowering phenotype citrus varieties and its application to production practice will become one of the effective technologies to promote the production and cultivation of citrus flowers in the future. In addition, the study of the effect of plant growth regulators on citrus flower formation, combined with cultivation methods such as ring cutting, can effectively regulate citrus flower bud differentiation, which will help achieve accurate flowering regulation in citrus production, so as to obtain higher economic value.

6. Funding: This work was supported by the Young and Middle-aged Talent Project of Hubei Provincial Education Department (grant number Q20181304).

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