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Physiology and Mechanism of pruning in fruit crops

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Abstract
Pruning is an essential horticultural practice for optimizing fruit production in fruit crops. The physiological and biochemical mechanisms behind pruning responses are complex and involve various aspects of plant growth, nutrient allocation, and hormonal regulation. This review summarizes the physiological effects of pruning, focusing on how it alters plant hormones, carbohydrate metabolism, gene expression, and resource allocation. Additionally, the review explores the molecular mechanisms that mediate these responses, including gene regulation, stress pathways, and the role of reactive oxygen species (ROS). Furthermore, the paper examines how pruning influences fruit yield and quality by modifying tree structure and enhancing resource distribution. This review aims to provide a comprehensive understanding of pruning's impact on fruit crops, with practical insights for improving fruit production efficiency.

Keywords: ROS, pruning, hormones, gene expression, stress

1. Introduction
Pruning, the selective removal of plant parts such as branches, buds, or shoots, is a crucial practice in fruit production systems worldwide. It is primarily used to control the shape, size, and health of the plant, improve light penetration within the canopy, and increase fruit yield and quality. While pruning's positive effects on fruit crops are well-established, the physiological and molecular mechanisms that underlie these effects are not fully understood. Understanding these mechanisms is essential for optimizing pruning strategies tailored to different fruit species and growth conditions. This review explores the physiological, biochemical, and molecular responses of fruit crops to pruning, highlighting the involvement of plant hormones, carbohydrate metabolism, stress responses, and gene regulation.

Pruning techniques in fruit crops
Pruning methods and timing can significantly influence the physiological outcomes of the plant. Various pruning strategies are employed depending on the fruit crop and desired objectives.

1.1. Pruning Methods
- **Heading Back:** This technique involves cutting back the terminal bud or branch to promote the growth of lateral buds and encourage branching. It is commonly used to control tree height and structure.
- **Thinning:** Removal of selected branches or shoots to reduce canopy density, improve air circulation, and ensure better light penetration.
- **Crown Pruning:** Involves the selective removal of the top portion of the plant, typically used to maintain a manageable height and improve fruiting potential.
- **Topping:** Removal of the uppermost parts of the tree to manage tree size and promote the growth of lateral branches.

1.2 Timing of Pruning
The timing of pruning significantly impacts its effectiveness, with two primary windows:
- **Dormant (winter) Pruning:** Performed during the dormant season, it typically promotes better bud formation, minimizes disease transmission, and allows for more vigorous growth in the subsequent growing season.

- **Summer Pruning:** Conducted during the growing season, it is mainly focused on controlling vegetative growth, improving light exposure to the tree canopy, and promoting fruit development.

2. Physiological effects of pruning on fruit crops
Pruning induces a variety of physiological changes in fruit crops, mainly driven by alterations in carbohydrate distribution, hormonal signaling, and growth patterns.

2.1 Hormonal Regulation
Pruning triggers changes in the levels of various plant hormones, which regulate key physiological processes such as growth, stress responses, and fruiting.

- **Auxins:** Pruning typically reduces the concentration of auxins at the cut site, which relieves apical dominance and promotes the growth of lateral shoots (Davies *et al*., 2010). This hormonal shift leads to increased branching and improved tree structure.
- **Cytokinins:** Pruning enhances cytokinin biosynthesis, which plays a role in cell division and lateral shoot formation. The redistribution of cytokinins after pruning promotes the development of new buds (Muller and Sheen, 2008) [9].
- **Gibberellins:** Pruning increases the levels of gibberellins, which stimulate shoot elongation and overall growth, particularly in younger trees (Owen and Klee, 2002) [11].
- **Abscisic Acid (ABA):** Higher levels of ABA are typically associated with stress responses and dormancy induction following pruning (Zhang *et al*., 2014) [15]. This helps regulate the tree's recovery and adaptation after injury.

2.2 Carbohydrate and Nutrient Redistribution
Pruning can lead to changes in the plant's carbohydrate and nutrient distribution. The removal of plant parts, especially leaves, results in reduced photosynthetic capacity, leading to a temporary decline in available carbohydrates. However, the plant compensates by redistributing stored carbohydrates to the remaining parts, particularly roots and developing buds (Cheng *et al*., 2007) [3]. Pruning can also reduce competition between vegetative and reproductive organs for nutrients, improving the growth of fruiting structures (Lakso and Smagula, 1997) [8].

2.3 Shoot and Root Growth
Pruning stimulates the growth of new shoots by releasing lateral buds from apical dominance. It also affects root development by promoting lateral root growth. Although above-ground biomass is reduced, pruning stimulates compensatory root growth, improving the plant's ability to take up water and nutrients (Alm *et al*., 2011) [1].

2.4 Flowering and Fruiting
Pruning can influence flowering and fruiting by altering resource allocation within the plant. By reducing excessive vegetative growth, pruning can redirect energy toward reproductive structures, leading to improved fruit set, fruit size, and fruit quality (Schaffer *et al*., 2015) [12].

3. Molecular Mechanisms of Pruning Responses
The molecular and genetic responses to pruning are key in mediating plant adaptation to the practice. Pruning-induced changes in gene expression and signaling pathways play a pivotal role in regulating the physiological changes observed.

3.1 Gene Expression and Transcriptomic Changes
Pruning activates the expression of genes involved in various metabolic and growth processes. Transcriptomic studies have shown that pruning leads to the up regulation of genes involved in:

- **Cell division and differentiation:** Pruning induces the expression of cytokinin-related genes, leading to enhanced cell division and shoot initiation (Kieber *et al*., 2007) [7].
- **Carbohydrate metabolism:** The redistribution of carbohydrates after pruning is regulated by the expression of starch and sugar metabolism genes, which help balance the plant's energy needs (Yang *et al*., 2014) [14].
- **Stress response:** The plant's response to mechanical injury includes the activation of genes involved in stress resistance and defense, including antioxidant enzymes (Chaves *et al*., 2016) [4].

3.2 Wound-Induced Signaling Pathways
Pruning causes mechanical wounding, which triggers a cascade of wound-induced signaling events. These events involve several key hormones, including:

- **Ethylene:** Pruning-induced ethylene production plays a central role in regulating the plant's response to injury, including tissue repair and stress tolerance (Ding *et al*., 2014) [6].
- **Jasmonic acid (JA):** JA is involved in promoting wound healing and enhancing defense responses following pruning (Schaller *et al*., 2013) [13].
- **Salicylic acid (SA):** SA mediates systemic acquired resistance (SAR), which provides the plant with enhanced resistance to pathogens after pruning (Mou *et al*., 2003) [10].

3.3 Reactive Oxygen Species (ROS) and Stress Responses
Mechanical injury from pruning generates reactive oxygen species (ROS), which are signaling molecules that activate stress-response pathways. ROS production triggers the activation of antioxidant systems and the expression of stress-related genes, helping the plant to cope with damage and restore normal physiological function (Caverzan *et al*., 2012) [2].

4. Impact of Pruning on Fruit Yield and Quality
Pruning affects fruit yield and quality by modifying plant structure, improving light penetration, and optimizing resource allocation.

4.1 Yield Enhancement
Pruning increases fruit yield by optimizing tree structure and enhancing light exposure to the canopy. Thinning and heading back increase fruit-bearing surface area, improving fruit set. Furthermore, the removal of excess vegetative growth reduces competition for resources, allowing the tree to focus its energy on developing fruit (Schaffer *et al*., 2015) [12].

4.2 Fruit Quality
Pruning improves fruit quality by improving light penetration, which enhances fruit color and sugar accumulation. It also helps maintain a healthy canopy,

reducing the incidence of diseases and improving fruit firmness and shelf life (Lakso and Smagula, 1997) [8].

5. Conclusion
Pruning plays a critical role in optimizing growth and maximizing fruit yield and quality in fruit crops. The physiological and molecular mechanisms underlying pruning responses are complex and involve alterations in hormone levels, carbohydrate metabolism, gene expression, and stress responses. By understanding these mechanisms, it is possible to design more effective and targeted pruning strategies that improve both the quantity and quality of fruit produced. Future research into the molecular and genetic responses to pruning will further refine our understanding of how pruning influences fruit crops and contribute to the development of best management practices.

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