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Factors Governing Citrus Flowering: Genetic, Environmental and Horticultural Insights

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Introduction

Citrus flowering period and intensity are influenced by species, age of the tree, and climate. Although fewer than 1% of blooms on a tree normally develop into full fruit, flower loads can reach up to 250,000 per tree. Prior to flower development, the buds must be activated by the interaction between exogenous and endogenous factors, which promotes the changes in their cells necessary for the formation of specific structures, such as inflorescences. They are used in cooking and medicine for centuries. In culinary arts, chefs use their fragrant oils and extracts to flavour foods and drinks. Warming weather in autumn and winter delaying the budding and flower initiation, consequently delay flowering, reduce flower number, and fruit set. High temperature during flowering stage increased abortion of fruit set in mandarin.

Factors Influencing Flowering in Citrus

1. Endogenous Control of Flowering

Endogenous control of flowering refers to the internal factors and mechanisms within plants that regulate the timing of flowering. These factors are influenced by genetic, physiological, and environmental cues, which interact to determine when a plant transitions from vegetative growth to reproductive growth.

a) Genetic Factors

Few genes, referred to as floral pathway integrators, control when blooming begins. The integration of diverse stimuli by these genes results in the induction of floral meristem identity genes. These genes, when active, trigger the ABC program of flower development, hence leading to the transition from vegetative to reproductive meristem. The main genes responsible for integrating the inductive stimuli of flowering are *Flowering Locus T* (*FT*), *Suppressor of Overexpression of Constans 1* (*SOC1*), and *Leafy* (*LFY*; Simpson and Dean, 2002).

b) The Presence of Fruit as a Repressor of Flowering

In *Citrus*, the fruit inhibits flowering when it remains on the Thus, in the Mediterranean basin, when the fruits are harvested before November, they hardly influence the following flowering, but if they are harvested later, the longer they stay on the tree, the more powerfully they will flower; if they are taken later, this inhibition will be partial. Under such conditions, the quantity of fruits also has a significant impact on the process; the more fruits, the less flowers that are produced the next spring. Both factors, harvest time and number of fruits, have statistical interaction (Martínez-Fuentes *et al*., 2010). Therefore, a late harvest of a large fruit load strongly weakens flowering in the following spring, while early low-yielding harvests have little effect on flowering.

c) Carbohydrate Levels

Carbohydrate consumption has been repeatedly emphasized as a factor promoting flowering. In alternative bearing cultivars, carbohydrate depletion occurs in all tree organs after a year of high crop and no flowers are produced in the following season (Martínez-Alcántara *et al*., 2015a). There is no evidence that the carbohydrate content of leaves, branches and roots limits flowering, but there may be an indirect effect.

d) Mineral Nutrition Status. The Role of Nitrogen

The In some cases, mineral element deficiencies cause a weakening of vegetative shoots that is usually accompanied by abundant flowering. In particular, there are trees with low nitrogen content in the leaves, abundant flowering and low vigor. These nutrient deficiency-induced changes in flowering indicate a nonspecific response related to vegetative weakness of the tree. Consequently, excess nitrogen causes vigorous vegetative development and reduces flowering (Agustí and Primo-Millo, 2020).

e) The Role of Plant Growth Regulators in Floral Organogenesis

Hormonal regulation of flowering and fruiting in citrus fruits is a complex process involving various plant hormones that interact to coordinate the growth and development of reproductive structures. Essential plant hormones such as gibberellins (GAs), auxins (Ax), cytokinin (CK), abscisic acid (ABA), and ethylene play crucial roles in different stages of citrus flowering and fruiting.

- GA has traditionally been linked to promoting vegetative shoot growth and antagonistic to flowering behaviour.

- The well-established role of Auxin in the formation of lateral organs involves a transient surge in indole-3-acetic acid (IAA) within vegetative meristematic tissue.
- Ethylene has been suggested as a potential flowering promoter, although not in citrus.

2. Environmental Factors Control of Flowering

Environmental factors play a significant role in influencing the timing and success of flowering in plants. These factors can vary widely depending on the species, and they interact with the plant's internal mechanisms to determine when flowering occurs.

a) Temperature

Citrus producing regions are commercially located in between 40° north and south latitude where the minimum temperature is generally more than -4° C. The optimum temperature for citrus growth is 25-30° C with the maximum rate of temperature photosynthesis occurring at 30° C. Flower induction, flowering intensity, and duration are correlated with temperature during the flowering period.

i. Effect of low temperature

Negative Effects of low on citrus fruits and flowers:

- At (-1.7° C) young fruits and flowers have died,
- Mature fruits are damaged at (-2° C).

ii. Effect of high temperature

The effects of high temperature have been noted during both vegetative and reproductive growth stages.

- Fluctuation flowering time and longevity.
- Decreased total yield through increases fruit drop.
- Reduce fruit quality (affect total sugars/ acidity ratio).

b) Water Stress

Water stress substitutes for chilling in areas of the tropics which have distinct rainy and dry season (Reuther, 1973). Rainfall of less than 100-150 mm per month is sufficient for flowering when the trees are relieved of stress. Scientist examined the flowering response to extended periods of water stress in orchards located in eight tropical countries. They found that a combination of vegetative and reproductive growth occurs approximately 20 to 28 days after the first effective rainfall or irrigation. Dry summer periods in subtropical regions sometimes induces flowering. It is triggered by withholding of irrigation in the subtropical climates of Italy.

3. **Horticultural Control of Flowering:**

In *Citrus*, yield and fruit quality largely depend on flowering intensity, so that in many cases its control is of great importance to improve the harvest (Agustí *et al.*, 2022). Flowering control is understood in a broad sense, and depending on the variety it will require flowering inhibition or promotion.

a) **Flowering Inhibition**

In some parthenocarpic citrus cultivars (e.g. 'Navelate' and 'Powell' Naval sweet orange), low yields are due to high flowering intensity (more than.100,000 flowers per tree). In these cases, 90–99% of the flowers abscise, and the more intense the flowering, the sooner they abscise (Agustí *et al*., 2022).

b) **Flowering Promotion**

Because GA reduces flowering, inhibitors of their biosynthesis have been used to promote flowering (Monselise et al., 1966). In fact, application of growth inhibitors such as B-nine, cycocel, benzothiazole or paclobutrazol during the induction period of flower buds on both the canopy and the ground increases the number of flowers (Monselise *et al*., 1966). Among them, the most widely used is paclobutrazol, which applied at a concentration of 1–2 g/l to OFF or medium yield trees increases the number of generative shoots and reduces that of vegetative shoots, thus increasing the number of flowers per tree.

Conclusion

In conclusion, the flowering of citrus trees is a complex process influenced by genetic, environmental, and horticultural factors. Genetic pathways involving FT, SOC1, and other genes regulate the transition from vegetative to reproductive growth, while environmental factors such as temperature and water availability play crucial roles in determining flowering intensity and fruit set. Horticultural practices, including managing fruit load and applying growth regulators, offer strategies to optimize flowering and improve yield consistency. Balancing these factors is essential for maximizing citrus production. By understanding and manipulating these variables, growers can mitigate the impacts of alternate bearing and environmental stressors, thereby ensuring more reliable harvests. Continued research into citrus flowering mechanisms promises further insights and innovations to support sustainable citrus cultivation practices worldwide. This holistic approach not only enhances agricultural productivity but also underscores the aesthetic and ecological importance of citrus flowers in global agriculture.

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