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Effect of Spring Fertilization on Early Blooming in Almond Trees: A Case Study from the Absheron Peninsula

Abstract

Almond cultivation is highly vulnerable to early spring frosts, particularly in climates where warming trends and sudden cold snaps coincide with flowering. Among several agronomic factors influencing almond phenology, spring fertilization—especially nitrogen input—has emerged as a potentially critical determinant of bloom timing. This three-year study (2023–2025) conducted on the Absheron Peninsula investigates how foliar-applied nitrogen fertilizers affect the flowering onset of the early-blooming Guara cultivar of *Prunus dulcis*. Trees receiving nitrogen in early March bloomed 7–11 days earlier than untreated controls. In 2025, a striking early bloom was observed just 12 days after nitrogen application. However, this advancement coincided with frost events that caused 20–40% yield losses. These findings underscore the dual role of nitrogen as both a growth stimulant and a potential risk enhancer. In frost-prone regions, nitrogen fertilization should be carefully timed to avoid ecological and economic losses. This paper integrates field data, comparative analyses, and a comprehensive review of the physiological mechanisms linking nitrogen to bud development and bloom induction.

Keywords: *Prunus dulcis, nitrogen fertilization, phenological shift, bloom advance, spring frost, Guara cultivar, Absheron Peninsula, climate risk management*

Introduction

Almond (*Prunus dulcis*) is one of the most economically important nut crops globally, with rising interest in cultivation extending beyond traditional Mediterranean zones into semi-arid and continental climates. Due to its inherently early phenological development, almond is particularly susceptible to spring frost damage, a leading cause of yield instability (Rodrigo, 2000; Egea et al., 2003).

Traditionally, bloom timing has been attributed to genetic and climatic factors—mainly the fulfillment of chilling and heat requirements (Campoy et al., 2011; Tabuenca, 1964). However, emerging evidence points to the significant impact of agronomic practices such as fertilization, irrigation, and pruning on bud development and floral timing (Fernandez-Escobar et al., 2004; Dag et al., 2010). Nitrogen, a key macronutrient for cell division and hormonal activity, has been particularly associated with the acceleration of bud break and bloom in temperate fruit crops (Marschner, 2012; Tromp, 1984).

Research

This study investigates how early-spring nitrogen fertilization affects bloom advancement in almonds grown in the unique microclimate of Azerbaijan’s Absheron Peninsula. The ‘Guara’ cultivar, known for its earliness and self-fertility, was selected due to its increasing use in local orchards.

2. Materials and Methods

2.1 Experimental Site

The trial was conducted at the Absheron Experimental Station (40.453866 N, 50.085366 E), located in a semi-arid zone with highly variable spring weather. The site has low annual precipitation (200–300 mm), a high summer evapotranspiration rate and poor organic matter content—conditions typical of the Absheron Peninsula.

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2.2 Orchard Design and Tree Selection

A 600 m² high-density orchard was established in 2021 with 45 *Guara* almond trees, spaced at 3 × 3 m. Eighteen trees were selected for this study and randomly assigned to three groups (6 each):

- **T1 – Main group** (early spring nitrogen fertilization)
- **T2 – Replicate group** (identical treatment for validation)
- **C – Control group** (no nitrogen until post-bloom)

2.3 Soil Characteristics

The soil was gray calcareous with the following parameters:

- pH: 6.3
- Organic matter: 2.6%
- Lime content: 26.4%
- Electrical conductivity: 0.38 dS/m
- Available nitrogen: Low
- Texture: Silty-clay

2.4 Fertilization Protocol

Fertilizers were applied foliarly on dry days:

- **March 5**: 32-2.5-32 (N: 32%, SO_3 : 32%)
- **April 4**: 13-0-46 (N: 13%, K_2O: 46%)
- **May 22**: 11-0-0 (N: 11%, MgO: 15.4%)
- **June 25**: 13-40-13 (N: 13%, P_2O_5 : 40%, K_2O: 13%)

Soil nitrogen content was monitored pre- and post-treatment using standard Kjeldahl analysis.

Conclusion

3.1 Flowering Phenology

In all three years, trees treated with nitrogen on March 5 entered bloom approximately 7–11 days earlier than untreated trees. The most dramatic result was observed in 2025: all nitrogen-treated trees bloomed by March 17, while untreated controls remained dormant until March 27–30.

3.2 Frost Damage and Yield Impact

In 2023 and 2025, frost events (March 18–21) occurred shortly after bloom initiation in nitrogen-treated trees. These trees exhibited visible floral damage (necrosis, abscission) and reduced fruit set. Estimated yield loss ranged between **20–40%**, depending on bud stage at frost time. Control trees, blooming later, escaped this damage and showed more uniform kernel development at harvest.

3.3 Bud Morphology and Growth Dynamics

Microscopic dissection revealed more advanced floral organ development in treated trees by mid-March, including faster ovule maturation and elongation of flower parts. This correlates with studies by Rodrigo and Herrero (2002), showing nitrogen's involvement in primordia expansion through hormonal pathways.

4. Discussion

4.1 Mechanism of Bloom Advancement

Nitrogen promotes rapid cell expansion and the synthesis of growth-regulating hormones, including cytokinins and gibberellins. These compounds have been linked to earlier and more vigorous bud development in almond and other Rosaceae (Sanchez-Perez et al., 2012; Tromp, 1984). Gibberellins, in particular, are known to reduce dormancy depth and hasten phenophase transitions (Dennis, 1994).

Furthermore, high nitrogen availability alters the carbon/nitrogen balance in tissues, promoting shoot elongation and reducing dormancy persistence (Blanke & Lenz, 1989). These biochemical processes likely explain the bloom acceleration observed in treated trees.

4.2 Risk Trade-Offs in Spring Fertilization

While nitrogen-induced early blooming may be beneficial under frost-free conditions, it poses a significant threat in regions like Absheron where late frosts are unpredictable. A similar dilemma has been noted in cherry, apricot, and plum production across Eastern Europe and Central Asia (Stoev et al., 2021).

Additionally, early blooming can lead to phenological desynchronization with pollinators, potentially affecting fruit set even in self-fertile cultivars like Guara (Martinez-Gomez et al., 2009).

4.3 Strategic Recommendations

To mitigate risks, nitrogen fertilization should be aligned with local chill-hour models and thermal time forecasts. Several decision-support models—such as Utah Model, Dynamic Model, or CHU accumulators—can help growers adapt nutrient schedules to local conditions (Fishman et al., 1987; Luedeling et al., 2009).

5. Conclusion and Recommendations

This study confirms that spring nitrogen fertilization significantly accelerates blooming in *Prunus dulcis*, particularly in the early-flowering Guara cultivar. However, this phenological shift comes at a cost: increased vulnerability to frost and potential yield reductions.

Recommendations for frost-prone regions:

1. **Delay nitrogen fertilization** until late April or after chill and heat thresholds are met.
2. **Adopt split nitrogen applications** to reduce hormonal spikes and avoid stress induction.
3. **Use phenology forecasting models** to adjust fertilization in line with bloom safety windows.
4. **Monitor bud development microscopically** to fine-tune timing in high-risk years.
5. **Experiment with low-nitrogen early-season alternatives** (e.g., micronutrients, seaweed extracts).

These recommendations are particularly relevant for almond-growing regions in Central Asia, Iran, Turkey and the Caucasus, where frost threats coincide with economic dependence on stable yields.

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