

and reproductive performance (Francesca et al., 2026). Several studies also show that higher density can increase plant height while reducing vegetative biomass per plant or modifying leaf area relationships, indicating that architectural responses are central to density adaptation rather than secondary effects (Tuan and Mao, 2015; Sievidov and Sievidov, 2020; Ayarna et al., 2021). For this reason, regulating planting density is not only a matter of fitting more plants into a field or greenhouse, but also a way of steering canopy structure, source-sink balance, and the conditions under which flowers set and fruits develop (Ansari et al., 2017; Evangelista et al., 2025).

Research on the effects of planting density on tomato growth and development shows a consistent trade-off between yield per plant and yield per unit area, although the exact optimum varies with cultivar, environment, and management system. In greenhouse tomato in northwest China, increasing density reduced fruit number per plant, mean fruit weight, and yield per plant, yet total yield increased, with an economic optimum of 3.7~4.4 plants/m². Similar responses have been reported in hydroponic and soilless systems, where raising density increased yield per square meter but often reduced average fruit weight and shifted yield toward greater fruit number per area (Ayarna et al., 2021). Studies in field and greenhouse conditions likewise show that moderate rather than extreme densities frequently maximize marketable or total yield, with reported optima near 25 974~28 571 plants/ha, 33 000~45 830 plants/ha, or about 3.5 plants/m² depending on genotype and production context (Tuan and Mao, 2015; Sievidov and Sievidov, 2020; Dinh and Dang, 2023). Even so, responses are not uniform: some studies found little effect on yield per hectare, others found cultivar-specific quadratic responses, and high-tunnel trials reported yield losses per plant of 32%~46% when density exceeded the locally suitable arrangement (Maboko and Du Plooy, 2018; Torres-Quezada and Gandini-Taveras, 2023; Evangelista et al., 2025).

Beyond total yield, density also influences fruit set characteristics, marketable yield, and quality traits that are directly relevant to commercial production. Excessively high density can hamper fruit set, reduce fruit size, lower sweetness and acidity, and increase the risk of flower abortion when assimilate supply per plant becomes limiting (Karpe et al., 2024; Francesca et al., 2026). In contrast, lower or moderate densities often improve fruit set rate, fruit number per plant, and individual fruit weight, as observed in field and greenhouse studies in Vietnam and Bangladesh (Tuan and Mao, 2015; Chau and Chinh, 2021). Density effects on reproductive traits are nevertheless context-dependent: under summer heat stress, plant density did not affect fruit set in heat-tolerant hydroponic cultivars, while in a greenhouse study blossom drop decreased as density increased to 3.5 plants/m² (Ayarna et al., 2021). Fruit quality responses are equally nuanced. Higher density often reduces fruit size and some market attributes (Haque and Sakimin, 2022), but some studies report limited change in qualitative traits across density ranges or even gains in selected compounds such as lycopene under particular light environments (Talpur et al., 2023; Evangelista et al., 2025). These mixed findings indicate that the effect of planting density on tomato performance cannot be judged from yield alone, because architecture, flower retention, fruit set, fruit growth, and quality formation respond simultaneously and sometimes in opposite directions (Caradonia et al., 2023).

This article analyzes the effects of planting density on tomato plant architecture, fruit set characteristics, and yield performance, with particular attention to the mechanisms by which density regulation influences population structure and yield formation. Previous studies have mainly focused on individual indicators, such as total yield, planting spacing, water productivity, or fruit quality, while the integrated relationships among canopy structure, reproductive processes, and final yield formation have received comparatively less attention. By synthesizing existing evidence on plant architectural traits, flower and fruit development, and yield responses, this article examines why moderate planting densities can improve yield per unit area, whereas excessive density may result in smaller fruits, reduced marketable yield, or lower productivity per plant. Because suitable planting density is jointly affected by cultivar architecture, production environment, and associated cultivation practices, the article further discusses density optimization under different production systems and the potential application of precision management technologies. The analysis provides a reference for efficient tomato cultivation, population structure optimization, and precision density management under different production conditions.