

7 Conclusion and Prospects

Planting density regulates tomato population performance by modifying plant architecture at both the individual-plant and canopy scales. Under constant high density, tomato shows a characteristic shade-response syndrome, including internode elongation, increased slenderness, higher specific leaf area, and lower assimilate availability per plant, while total plant weight per unit area increases and then saturates. In spring greenhouse tomato, increasing density increased plant height and reduced vegetative mass per plant, with 3.5 plants/m² giving the best balance among vegetative mass, height, and leaf area. Variety-specific responses reinforce that architecture mediates density effects: in the Brazilian Savanna, the compact hybrid U-2006 showed little yield response to density, likely because its smaller habit limited changes in leaf area index and light interception, whereas other hybrids responded positively up to 40 000 plants/ha. Seedling studies also show that density changes structural quality early, with low density improving health index and dry matter ratio, while high density can increase radiation use efficiency, indicating that architectural regulation begins before transplanting.

Appropriate planting density promotes fruit set and yield efficiency by balancing reproductive sink demand with canopy resource capture. Moderate densities often maximize fruit set, fruit number per plant, fruit weight, and yield per plant, as shown by optima around 25 000 plants/ha in greenhouse Vietnam and 25 974 plants/ha in field Vietnam. In Bangladesh, 25 000 plants/ha maximized flowers per cluster, fruits per cluster, fruits per plant, and yield per plant, while 28 571 plants/ha maximized total and marketable yield, illustrating the consistent trade-off between plant-level and area-level productivity. Comparable patterns appear in protected systems: higher densities increased yield per square meter in hydroponic and soilless tomato, including 3.5 plants/m² in Golestan, 25 plants/m² for determinate closed hydroponics in spring/summer, and 3.7~4.4 plants/m² as the economic optimum in northwest China's solar greenhouses. But when density becomes excessive, fruit number per plant, average fruit weight, and yield per plant decline, and flower abortion becomes more likely, especially for distal flowers under assimilate shortage.

Precision density management is emerging as a major direction for high-efficiency tomato production because fixed spacing recommendations cannot accommodate variation among cultivars, seasons, pruning systems, and stress environments. Dynamic spacing that maintained 75% or 90% ground coverage preserved fruit quality close to low density while more than doubling harvestable yield per area relative to constant low density, showing that density can be managed as a moving canopy target rather than a static initial decision. This logic is strengthened by evidence that density optima shift with management context, including bunch number per plant in hydroponics, fertilizer regime in greenhouse production, grafting under abiotic stress, and season in determinate closed hydroponics. New functional-structural models now identify optimal canopy configurations for mechanized greenhouses and vertical farming, including an east-west layout at 39 000 plants/ha in Chinese solar greenhouses and density-responsive ideotype design for dwarf tomato indoors. Taken together, the evidence supports a shift from uniform density recommendations toward canopy-based, cultivar-specific, and dynamically adjusted density regulation to improve yield, quality, and resource-use efficiency across tomato production systems.

Conflict of Interest Disclosure

The author affirms that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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