

characteristics. In three-truss tomato, higher density increased fruit yield per area relative to lower density, consistent with improved interception at the crop level rather than greater productivity of individual plants (Higashide, 2022). Likewise, in dwarf tomato, increasing density raised efficiency in converting incident and intercepted light into red-ripe fruits, and total plant dry weight per square meter increased with density before saturating at the highest constant density. However, per-plant assimilate availability fell under constant high density, and final whole-plant dry weight per area was not higher than a dynamic 90% ground-cover treatment, suggesting diminishing returns once crowding becomes excessive (Karpe et al., 2024).

Photosynthetic responses themselves are nuanced, because dense canopies can increase canopy light capture while depressing photosynthesis in shaded leaves. In winter greenhouse tomato, leaf photosynthesis was higher in the movable-bench and lower-density treatments than in the fixed high-density treatment, and those treatments also maintained greater leaf area and shoot dry weight (Jiang et al., 2017). By contrast, a recent study found that high density unexpectedly enhanced photosynthetic rates despite activating shade-avoidance morphology, implying that moderate canopy shade can sometimes improve physiological efficiency depending on water status and environment (Francesca et al., 2026). Classic modeling work further suggests that plant density has a smaller direct effect on dry matter partitioning than on dry matter production, because partitioning is governed more strongly by sink strength and fruit load, while LAI simulation remains highly influential for crop growth prediction. Seedling and greenhouse studies also show that higher density can raise radiation or light-use efficiency even when individual plants are smaller (Xu et al., 2024; Zhang et al., 2025), so the architectural effect of density on photosynthesis is best understood as a balance between greater canopy capture and lower per-plant light availability. In sum, planting density modifies tomato architecture by coordinating morphological plasticity, canopy organization, and crop-level carbon gain, with moderate or dynamically adjusted densities often producing the most favorable balance between structural development and biomass accumulation (Higashide, 2022; Karpe et al., 2024).

3 Effects of Planting Density on Tomato Fruit Set Characteristics

3.1 Effects on inflorescence formation and flowering dynamics

Planting density influences inflorescence formation mainly by altering the balance between vegetative growth, assimilate supply, and the number of reproductive sites carried per unit area. In protected tomato, increasing density raised the number of trusses per ground area, but plants did not convert all additional flowers into fruits, indicating that reproductive structure formation can outpace the plant's capacity to sustain fruiting. In dwarf tomato pruned to a fixed flower number, high density still reduced reproductive success, showing that density effects persist even when the potential floral load is standardized (Karpe et al., 2024). Studies evaluating agronomic components also show that density significantly affects clusters per plant, flowers per cluster, distance between clusters, and blossom drop, confirming that flowering dynamics are structurally responsive to crop crowding.

The direction of response varies with production system and genotype. In Bangladesh field tomato, lower density increased flowers per cluster and supported higher fruits per cluster and fruits per plant, suggesting that wider spacing favors stronger reproductive expression per individual plant. In a spring greenhouse in Ukraine, density had little effect on the timing of developmental phases, indicating that planting density can modify reproductive intensity more than phenological schedule (Sievidov and Sievidov, 2020). Additional evidence from seedling-density work shows that higher nursery density later increased flower number and yield per plant after transplanting, likely because early restriction of vegetative growth redirected photoassimilates toward inflorescences in formation (Moreno-Pérez et al., 2021). More broadly, yield analyses across genotypes identify flowers per cluster and fruits per cluster as important positive contributors to yield, which helps explain why density effects on flowering traits propagate into final productivity (Muntaha et al., 2023; Ramana et al., 2025).

3.2 Effects on fruit set rate and fruit development

Planting density has a clear effect on fruit set rate and fruit development, but the response is not monotonic. Several studies found that moderate or lower densities improved fruit set, fruits per cluster, fruits per plant, and