

individual fruit weight. In Vietnam field conditions, 25 974 plants/ha gave the best fruit set, fruit number, fruit weight, and overall yield (Tuan and Mao, 2015). In greenhouse tomato, 25 000 plants/ha produced the highest fruit setting rate at 75.35%, along with 94.84 fruits per plant and 113.24 g average fruit weight (Chau and Chinh, 2021). A similar pattern appeared in Bangladesh, where 25 000 plants/ha maximized fruits per cluster, fruits per plant, and fruit yield per plant, while 28 571 plants/ha maximized total and marketable yield.

At higher density, tomato often compensates by increasing yield per area despite weaker per-plant fruiting. In soilless greenhouse culture, raising density to 3.5 plants/m² increased yield per square meter in all cultivars, and fruit yield per square meter correlated strongly with fruit number per plant but negatively with average fruit weight. In dwarf tomato, despite lower fruit number per plant, constant high density produced 11.1 kg/m² and 72% flower fruiting success, but fruit number per plant was lower and distal flowers were preferentially aborted, consistent with assimilate limitation during fruit set (Karpe et al., 2024). Earlier protected-cultivation work reached a similar conclusion: tomato adjusts the number of set fruits by aborting excess flowers, and 6.7 plants/m² appeared to be the upper practical limit for maximizing set fruit number under the tested leaf-to-inflorescence balance. Not all systems respond identically, however. In one field study, higher density reduced fruit number and yield per plant but did not change marketable or total yield per hectare (Maboko and Du Plooy, 2018), while under combined drought and high density, yield per plant declined even though high density alone increased yield per hectare and produced larger fruits in irrigated plants (Francesca et al., 2026).

3.3 Effects on fruit quality formation

Fruit quality formation is one of the most density-sensitive outcomes, but evidence is mixed because different quality traits respond in different directions. Strong evidence shows that constant high density reduces individual fruit size and several market traits. In dwarf tomato, high density lowered fruit fresh weight, fruit size, hardness, total soluble solids, and citric acid content, and made soluble solids less uniform across fruits. That same study found that dynamic spacing maintained quality similar to low density while preserving much higher yield per area, suggesting that quality losses are tied more to sustained crowding than to temporary canopy closure (Karpe et al., 2024). In organic field tomato, higher density reduced marketable yield per plant mainly through fewer fruits, but it also reduced fruit loss from infection, showing that density can alter fruit health as well as intrinsic quality (Caradonia et al., 2023).

Other studies indicate that some quality attributes remain stable or even improve at higher density depending on environment and trait measured. In hydroponic greenhouse tomato, density affected pericarp thickness, pH, uniform ripening, and total soluble solids, but the highest density increased TSS only in one cultivar and lowered juice pH in two cultivars, indicating a genotype-dependent quality response. Under open-field high density, fruits showed lower titratable acidity but 72.75% higher lycopene, with no difference in firmness, suggesting that denser canopies can improve selected nutritional traits even when flavor chemistry shifts (Francesca et al., 2026). Broader genetic studies help interpret this variability: fruit weight, TSS, titratable acidity, pericarp thickness, and lycopene all vary widely among genotypes and are strongly tied to yield or processing quality, so density effects on fruit quality are likely filtered through cultivar-specific sink strength and biochemical capacity (Muntaha et al., 2023; Naik et al., 2025; Ramana et al., 2025).

4 Effects of Planting Density on Tomato Yield Performance

4.1 Effects on individual plant yield and population yield

Increasing planting density generally reduces yield per plant while improving land-use efficiency and often increasing yield per unit area (Maboko and Du Plooy, 2018; Haque and Sakimin, 2022). In greenhouse dwarf tomato, constant high density produced 111 g fruit fresh weight per plant but the highest harvestable yield per area, 11.1 kg/m², showing the classic trade-off between plant-scale and area-scale productivity (Karpe et al., 2024). In Bangladesh field tomato, 25 000 plants/ha gave the highest fruit yield per plant, but 28,571 plants/ha gave the highest total and marketable yield. In Vietnam field conditions, 25 974 plants/ha produced the maximum fruit yield, indicating that moderate rather than maximal density can optimize total yield when crowding starts to depress reproductive performance (Tuan and Mao, 2015).