

Yield formation under different planting densities is further mediated by changes in crop architecture, dry matter accumulation, and assimilate partitioning. Evidence from bell pepper indicates that higher population density increases fruit yield per land area and that node number is a major yield component underlying density responses, pointing to structural adjustment of the plant population as a key mechanism of productivity change. Greenhouse research also shows that density alters leaf area index, canopy interception of photosynthetically active radiation, and dry matter partitioning between vegetative and reproductive organs; specifically, leaf dry matter partition increases and fruit dry matter partition decreases as density rises, while harvest index remains closely related to cumulative intercepted radiation. Together, these findings suggest that pepper yield formation under density stress depends not only on plant number, but also on how effectively the crop canopy captures light and directs assimilates toward fruit production.

Against this background, a review of planting density effects on yield formation in pepper is timely because published results indicate both broad agreement and important context dependence across cultivars, production systems, and target quality traits. For example, organic protected cultivation showed that higher densities increased yield and shortened the production cycle without necessarily reducing fruit size or quality in some genotypes, with the highest yields occurring at 6 to 8 plants/m² depending on genotype (Silva et al., 2021). In greenhouse bell pepper, marketable yield responded positively and linearly to increased density even though fruit set per plant declined, reinforcing that optimal density must be defined at the crop-population level rather than at the single-plant level. Therefore, the objective of this review is to synthesize current evidence on the importance of planting density management in pepper production, clarify the mechanisms linking density to yield formation, and identify how density interacts with genotype, canopy traits, and cultivation environment to shape both productivity and fruit quality.

2 Planting Density Regulation and Population Structure of Pepper

2.1 Canopy architecture and light interception

Planting density directly regulates pepper population structure by changing canopy closure, leaf area development, and the spatial pattern through which incoming radiation is distributed within the crop. In greenhouse sweet pepper, canopy light interception increased progressively after planting and reached about 92% at maturity, showing that dense, trained pepper stands can capture most incident radiation once the canopy is fully developed. Density also shapes canopy size through its effect on leaf area index, which follows a logistic increase after planting and reaches density-dependent maxima under protected cultivation. Together, these results indicate that population density is not simply a numerical stand attribute, but a structural regulator of canopy formation that determines how quickly pepper crops occupy space and intercept available light.

The effect of density on light interception depends not only on plant number but also on canopy geometry and within-row shading. In glasshouse pepper, light transmission below the canopy varied strongly by position and time of day, with much less light beneath rows than in the gaps between them, indicating that denser canopies create pronounced internal light gradients. At the same time, studies of pepper growth under modified light environments show that reduced light promotes taller plants and wider crowns through increases in canopy spread and branching, which helps explain why density-driven crowding often induces architectural adjustment as plants compete for radiation (Febrianto et al., 2024). Thus, the influence of planting density on pepper light capture operates through both canopy closure and plastic changes in plant architecture.

2.2 Plant growth and biomass accumulation

Planting density alters the balance between individual plant growth and biomass production per unit land area. Field evidence in sweet pepper shows that increasing density reduces vegetative growth traits such as lateral stem number and leaf dry matter, while also lowering fruit weight and yield per plant, even though total yield per hectare increases (Aminifard et al., 2012). A similar trade-off was reported under open-field conditions in another pepper study, where higher densities produced taller plants and greater total fruit production, whereas lower densities improved yield per plant and the proportion of marketable fruit. These findings show that density intensifies competition among neighboring plants, shifting performance away from individual vigor and toward collective productivity per unit area.