

Research Insight

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Effects of Planting Density on Yield Formation in Pepper

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Abstract Planting density is a critical agronomic factor regulating crop population structure, resource utilization, and yield formation in pepper (*Capsicum annuum* L.) production. Improper planting density can lead to excessive competition for light, water, and nutrients, resulting in reduced photosynthetic efficiency, imbalanced biomass allocation, and unstable yield performance. This review summarizes the effects and underlying mechanisms of planting density on pepper growth, physiological processes, yield components, and fruit quality. Changes in planting density influence canopy architecture, leaf area index, light interception, root development, and microclimatic conditions, thereby affecting carbon assimilation and resource acquisition. Moderate planting density optimizes source–sink relationships, improves photosynthetic capacity, enhances nutrient and water use efficiency, and promotes reproductive development, including flowering, fruit setting, and fruit expansion. Excessive density often causes canopy shading, increased disease risks, and reduced individual plant productivity, whereas insufficient density limits land resource utilization and decreases population yield potential. Furthermore, this review discusses the physiological, ecological, and molecular mechanisms involved in density-induced adaptation, as well as strategies integrating planting density with irrigation, fertilization, and precision agriculture technologies. A case study is presented to demonstrate the practical application of density optimization for improving pepper yield formation and production efficiency. Future research should focus on developing dynamic density management strategies based on cultivar characteristics, environmental conditions, and intelligent agricultural technologies to achieve sustainable and high-yield pepper production.

Keywords Planting density; Pepper production; Yield formation; Canopy architecture; Resource use efficiency

1 Introduction

Pepper is an economically important vegetable crop in which yield and fruit quality depend strongly on how efficiently light, space, water, and nutrients are captured and converted into marketable fruit. Within this production system, planting density is one of the most practical management variables because it directly determines canopy structure, radiation interception, and the intensity of competition among neighboring plants. Recent agronomic work in pepper has therefore treated density management as a central component of yield improvement strategies rather than as a simple spacing decision. In field and protected systems alike, increasing density can improve land-use efficiency and raise output per unit area, especially when it is coordinated with cultivar choice and nutrient supply (Tian et al., 2024). In organic sweet pepper, higher planting density has likewise been proposed as a way to reduce production costs and increase fruit production within limited physical space, highlighting its relevance not only for biological productivity but also for production economics and system sustainability (Silva et al., 2021).

The relationship between planting density and pepper yield formation is complex because yield per unit land area and yield per plant do not respond in the same way. Multiple studies show that as density increases, total yield per hectare often rises, whereas individual plant performance tends to decline because each plant has access to fewer resources. In sweet pepper grown under field conditions, increasing plant density reduced fruit weight, fruit volume, and yield per plant, yet total yield per hectare still increased, indicating a compensatory population effect (Aminifard et al., 2012). Comparable patterns were reported in paprika pepper, where yield per hectare increased mainly because fruit number per unit area increased with density, while fruit number and dry fruit weight per plant declined and gains became marginal beyond very high densities, suggesting the existence of an agronomic optimum rather than an unlimited positive response.