

### **6.3 Regulatory effects of air humidity and CO<sub>2</sub> concentration on tomato growth in protected systems**

Air humidity and CO<sub>2</sub> concentration are important factors influencing tomato growth in protected environments, and they regulate plant physiological activity by affecting stomatal behavior, transpiration, and carbon assimilation processes. Appropriate air humidity helps maintain stomatal opening and transpiration-driven transport, whereas excessively high or low humidity can negatively affect plant growth. When the air is too dry and the vapor pressure deficit (VPD) is high, transpiration increases and stomata may close, reducing CO<sub>2</sub> assimilation rates. Conversely, excessive humidity restricts transpiration, affects mineral nutrient transport, and increases the risk of physiological disorders such as blossom-end rot. Even when VPD differences within the greenhouse are only about 0.6 kPa, significant differences in plant and fruit growth rates may occur (Šalagovič et al., 2024). In addition, humidity fluctuations can influence stomatal conductance and photosynthetic rates under fluctuating light conditions (Shi et al., 2024).

CO<sub>2</sub> concentration is another important regulatory factor that enhances photosynthetic potential in protected environments. Increasing environmental CO<sub>2</sub> concentration from approximately 400 ppm to 800-1 000 ppm can significantly increase leaf area, chlorophyll content, and net photosynthetic rate, thereby promoting dry matter accumulation and yield formation (Amarasinghe et al., 2025). This stimulatory effect is more pronounced under suitable light and temperature conditions, because photosynthesis responds more effectively to increased carbon supply under these conditions. However, excessively high CO<sub>2</sub> concentrations are not always beneficial. In cherry tomato production, the optimal CO<sub>2</sub> concentration under moderate light conditions is approximately 450-510 ppm, whereas excessively high CO<sub>2</sub> may reduce certain quality parameters through dilution effects (Arshad et al., 2024). Therefore, in protected tomato production, CO<sub>2</sub> regulation must balance the improvement of yield potential with the maintenance of fruit quality.

## **7 Cultivation Management Measures for Achieving High and Stable Yields in Protected Tomato Production**

### **7.1 Optimization of canopy structure through rational plant density and pruning**

Rational plant density and pruning (including side-shoot removal) are important cultivation measures for achieving high and stable yields in protected tomato production. Their core objective is to optimize canopy structure so as to coordinate the relationship among yield per unit area, individual plant light interception, and assimilate distribution. The canopy structure of protected tomatoes directly affects canopy light interception efficiency, the distribution of temperature and humidity within the canopy, and the balance between vegetative and reproductive growth, thereby exerting a significant influence on yield stability (Figure 6). Planting arrangements-such as row orientation, plant spacing, row spacing, and furrow spacing-often have a greater impact on canopy radiation interception, temperature distribution, and dry matter accumulation than individual plant structural traits. Moderately increasing plant spacing can improve light interception by individual plants and enhance fruit development. In protected production systems, moderate dense planting can increase leaf area per unit area and improve canopy light interception. However, excessively high planting density can deteriorate ventilation and light conditions, intensify competition among plants, and increase the risk of disease. In solar greenhouses, adopting an east-west row orientation combined with relatively wider row spacing can significantly enhance canopy light interception and photosynthetic capacity, increasing yields by approximately 4%-10% across different seasons (Li et al., 2024).

In recent years, dynamic planting density strategies have provided new approaches to canopy management in protected tomato production. By maintaining relatively high planting density during early growth stages to maximize canopy light interception, and then reducing density in later stages, it is possible to alleviate problems such as reduced fruit size and quality caused by excessive crowding, thereby balancing high yield and fruit quality (Karpe et al., 2024). Pruning and side-shoot removal further optimize canopy structure by controlling branch number and leaf area distribution, improving canopy ventilation and light penetration while promoting assimilate allocation to flowers and fruits. In high-wire cultivation systems, training a plant into two main stems can increase yield per plant and improve spatial utilization efficiency without increasing plant number. In addition, appropriate leaf removal is also an important component of refined canopy management. Studies show that data-driven leaf