

Turboroot in greenhouse tomato production can increase chlorophyll content and promote vegetative growth; when combined with soil improvement measures, yields can increase by approximately 16%-45% (Avasiloaiei et al., 2025). At the same time, appropriate levels of NPK fertilization are also important for stable fruit set, with moderate fertilization levels optimizing photosynthetic rates and fruit quality.

In addition to growth regulators, canopy structure and environmental conditions also influence fruit set stability. Excessively high planting density or excessive branching can intensify resource competition among fruits, resulting in reduced single fruit weight and increased fruit drop (Karpe et al., 2024). Therefore, rational plant density and pruning management can increase assimilate supply to inflorescences, thereby promoting fruit set and fruit retention. Improving the light environment can also increase fruit set rates. For example, LED supplemental lighting has been shown to increase fruit set rate by about 46% and accelerate fruit maturation. Under protected cultivation conditions, weaker air movement and reduced insect activity often result in lower pollination efficiency compared with open-field conditions. Therefore, pollination efficiency can be significantly improved through manual vibration, mechanical vibration, or bumblebee pollination, which enhance pollen release and fertilization success. These measures help reduce flower and fruit drop and stabilize yield.

## **8 Future Development Trends in High and Stable Yield Cultivation of Protected Tomatoes**

With the rapid development of sensor technology, automation, artificial intelligence, and data science, protected tomato production is gradually shifting from experience-driven management to data- and model-driven systems. A key characteristic of future high-yield and stable greenhouse production will be the use of intelligent environmental control technologies to monitor and regulate key factors such as temperature, humidity, light intensity, CO<sub>2</sub> concentration, irrigation, and nutrient solution supply in real time through closed-loop control systems. This approach enables more precise production management. Currently, high-tech greenhouses have increasingly integrated technologies such as water and fertilizer sensors, supplemental lighting systems, and microclimate control software, forming automated production systems that combine environmental sensing, decision analysis, and operational control. Compared with traditional experience-based management, intelligent control systems can dynamically optimize environmental parameters by integrating real-time and historical data, thereby improving resource-use efficiency and stabilizing yield levels. In recent years, greenhouse control platforms and predictive models based on the Internet of Things (IoT) have further promoted the transition of protected agriculture from passive regulation to proactive prediction. Meanwhile, emerging concepts such as autonomous greenhouses and digital twin greenhouses are providing important directions for the future intelligent upgrading of protected tomato production. In addition to improving yield, intelligent environmental regulation can also reduce environmental burdens by optimizing energy and water-fertilizer utilization efficiency, thereby providing technical support for sustainable protected tomato production.

Against the backdrop of climate change and increasing intensification of protected cultivation systems, the breeding of high-yield and stress-resistant varieties, together with grafting technology, will become important foundations for stable tomato production. Modern tomato breeding is gradually shifting from a single focus on high yield to the improvement of multiple traits including high yield, superior quality, stress tolerance, and adaptability to protected cultivation environments. This transition is increasingly supported by technologies such as marker-assisted selection, molecular design breeding, and gene editing, which are used to develop new varieties resistant to high temperature, salinity, and diseases. Tolerance to stresses such as high temperature and waterlogging in tomato is associated with multiple genetic effects, and some superior hybrid combinations can still maintain relatively high fruit set and yield under adverse conditions. Therefore, future breeding efforts should not only focus on fruit quality and marketability, but also incorporate root system traits, reproductive stability, and stress-resistance physiological characteristics as key selection criteria. At the same time, grafting cultivation can combine high-quality scions with stress-resistant rootstocks, improving plant adaptability to complex environments and extending the fruiting period. Recent studies have also revealed that certain stress-resistance traits can be regulated by rootstocks and transferred to the scion, providing new directions for targeted rootstock breeding and research on rootstock-scion interactions.