

parameters such as temperature, humidity, light, and substrate moisture content, and realizes model-driven dynamic regulation through a cloud computing platform. The prediction system built with machine learning algorithms such as random forests and support vector regression can effectively avoid low temperature stress and improve photosynthesis efficiency and energy utilization (Chen et al., 2022; Samaranayake et al., 2022; Mubarakah et al., 2023; De Oliveira Bernardo et al., 2024; Wang et al., 2025). Comprehensive practice shows that the system has significant advantages in maintaining fruit consistency and can reduce labor management costs by more than 30%.

5.2 Seasonal crop rotation and soil fatigue mitigation technology

Innovative environmental control technology provides solutions for off-season production. Through the combined application of shading system and phase change energy storage device, greenhouse facilities can maintain a suitable cultivation temperature of 18 °C-25 °C in the high temperature season, successfully realizing the commercial cultivation of summer strawberries (Miyoshi et al., 2013; Thanthong et al., 2024). This technical system can not only stabilize the yield level, but also show good adaptability in ensuring fruit quality.

Multi-dimensional comprehensive management strategies are required for the prevention and control of continuous cropping obstacles. Physical disinfection technology (steam sterilization, solar disinfection) can effectively reduce the base number of soil pathogens; scientific rotation systems and intercropping of non-host crops can block the transmission chain of pests and diseases (Kang et al., 2024); regular disinfection of facilities can prevent the cross-transmission of pathogenic microorganisms (Hernández-Martínez et al., 2023; Kang et al., 2024). Deeply integrate traditional prevention and control methods with modern facility systems to provide technical support for the sustainable development of the strawberry industry.

6 Comprehensive Case Study on Environmental Control for High-quality Strawberry Cultivation Throughout the Year

6.1 Representative case study on regional year-round environmental control

In Japan and some temperate regions of Europe, large greenhouses are equipped with advanced environmental control systems - covering temperature, light, and carbon dioxide regulation - to achieve stable and high yields of strawberries throughout the year. Taking Japan's industrial greenhouses as an example, it uses a moving bed system and comprehensive environmental control methods (light supplementation, carbon dioxide enrichment, and precise temperature control), and the yield is doubled compared with traditional systems. These facilities improve yield and fruit quality by optimizing planting density and environmental parameters, especially when June-bearing varieties are selected and customized light supplementation solutions are used (Hidaka et al., 2016). China's solar greenhouses use opaque photovoltaic (OPV) panels to shade the sun, combined with solar heating, to maintain the temperature at 20.5 °C-27.4 °C and the light intensity (PAR) at 387~437 $\mu\text{mol}/\text{m}^2/\text{s}$, which increases the yield by 1.2 times compared with the unshaded control group, and the soluble solids content of the fruit is also higher (Tang et al., 2020).

The core of environmental control in tropical and subtropical regions is to alleviate the problems of overheating and humidity. Covering technology (especially black plastic mulch) and shade nets have been proven to regulate soil temperature and humidity - in the humid tropical regions of India, such measures can increase fruit yield by 68% and improve the content of phytochemicals (Misra, 2023). The Saudi Arabian experimental area adopts a 20 m × 8 m layout to test the effects of different colored shade nets on plant growth (Figure 3). In greenhouses, colored shade nets (e.g., beige or green) can optimize light quality and temperature, with beige shade nets achieving optimal yields and improving plant physiological characteristics (Alhelal et al., 2024). These improvements allow strawberry to achieve off-season and year-round production under otherwise limited climatic conditions.