

bacterial pathogens, and cucumber is particularly characterized by foliar fungal diseases favored by high relative humidity (Fanourakis et al., 2026). In cucumber specifically, downy mildew remains one of the most destructive diseases, and its development is tightly linked to moisture availability. Experimental work has shown that *Pseudoperonospora cubensis* forms abundant sporangia when infected tissues are wetted or exposed to 100% relative humidity, whereas only a few sporangia are produced at 90% relative humidity. These findings indicate that relatively small differences in humidity can determine whether pathogen reproduction is strongly amplified or constrained. More broadly, humidity interacts with temperature to regulate infection timing, sporulation intensity, and epidemic development, which explains why disease outbreaks in cucumber houses often occur rapidly once favorable microclimatic thresholds are reached. Because greenhouse cultivation often involves dense canopies and restricted air movement, unmanaged humidity can quickly create persistent infection windows that are difficult to reverse after symptoms appear.

Research over the last decade has strengthened the case for humidity-based disease prevention by identifying actionable thresholds and revealing similar moisture dependence across multiple cucumber pathogens. In greenhouse trials on cucumber downy mildew, relative humidity above 90% favored disease development, whereas keeping humidity below 89% protected plants from infection; under early infection, ventilation-based humidity reduction decreased infection percentage by 95.8% and disease severity by 70% (Khudhair and Aljarah, 2023). Comparable patterns have also been reported for cucumber target leaf spot caused by *Corynespora cassiicola*, for which moisture had a stronger effect than temperature on sporulation on living plants, maximum spore production occurred at 100% relative humidity, and only a few spores formed at 75% relative humidity (Zhao et al., 2022). Together, these studies suggest that humidity regulation is not relevant to a single disease only, but is a broader mechanism for suppressing inoculum production and secondary spread in cucumber production systems. At the same time, reliance on fungicides alone is increasingly problematic because repeated use raises concerns about residues, environmental contamination, and resistance development, which further motivates non-chemical strategies centered on environmental control (Abdelfatah et al., 2025).

Against this background, current research is moving from descriptive observation toward predictive and automated humidity management. Forecasting models for cucumber downy mildew have already been proposed to reduce epidemic risk by combining records of pathogen presence with temperature and relative humidity in greenhouse and field settings, highlighting the value of climate-informed decision support. At the production level, modern protected cultivation is also beginning to use sensor-based and AI-assisted control systems, with remotely managed greenhouse compartments showing that artificial intelligence can perform well in cucumber climate regulation, and IoT-based microclimate systems maintaining more favorable humidity conditions while increasing yield by 41.6% per vine under protected cultivation. Therefore, the objective of this paper is to examine how humidity control influences disease occurrence in cucumber production by integrating evidence on microclimate regulation, humidity-pathogen interactions, and emerging predictive control strategies. Particular attention is given to the role of relative humidity in shaping disease-conducive environments, to the potential of ventilation and automated monitoring as preventive tools, and to the broader significance of humidity management for sustainable cucumber health and quality control.

2 Humidity Characteristics and Microclimatic Regulation in Cucumber Production Systems

2.1 Sources and dynamics of humidity variation in cultivation environments

Humidity variation in cucumber production systems arises from the interaction of greenhouse enclosure, crop transpiration, soil or substrate evaporation, and external weather forcing. Protected cultivation stabilizes the environment for year-round production, but that same enclosed microclimate can also retain moisture and increase the probability of pathogen-favorable conditions (Fanourakis et al., 2026). In cucumber houses specifically, total radiation, air temperature, and humidity show strong seasonal variation, and average nighttime relative humidity is significantly associated with yield, indicating that humidity is not static but part of a continuously shifting greenhouse climate system. The temporal pattern of humidity is especially important because many cucumber diseases respond to short periods of high moisture rather than daily averages alone. For downy mildew, infection