

8.2 Climate change and disease dynamics

Climate change is expected to increase disease pressure by altering temperature, humidity, and rainfall patterns, thereby shifting pathogen distributions and promoting outbreaks. Studies predict that many plant pathogens will expand their geographic ranges and occur more frequently, which could significantly impact tomato production and food security (de Almeida et al., 2020). Field evidence from Nepal shows that changes in temperature and precipitation are closely associated with increased incidence of late blight, leaf curl disease, and black spot in tomato, forcing farmers to use more pesticides to maintain yields (Bhandari et al., 2021). In addition, emerging viruses such as ToBRFV are spreading into new regions, a process partly driven by both climate change and global trade.

8.3 Future breeding directions

Future breeding will increasingly rely on multi-omics integration and advanced analytical approaches. The combined application of transcriptomics, ionomics, and other omics technologies in tomato has identified candidate genes and SNPs associated with resistance to late blight and ToBRFV, providing a basis for developing more precise molecular markers and functional targets (Deb et al., 2023). Further studies emphasize the need to integrate genomics, transcriptomics, metabolomics, and effectomics to better understand resistance mechanisms and guide the design of durable resistance (Adhikari et al., 2020).

Artificial intelligence-assisted breeding and phenotyping are becoming key tools. Image-based high-throughput phenotyping in tomato bacterial wilt research can detect subtle quantitative differences and identify new QTLs earlier than manual scoring. In addition, integrating multi-omics data with machine learning to predict resistance phenotypes is considered an important future direction, highlighting the potential of intelligent breeding platforms to accelerate the development of disease-resistant crops (Cembrowska-Lech et al., 2023).

Author Contributions

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Conflict of Interest Disclosure

The authors affirm that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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