

and stomatal conductance relative to drip irrigation alone (Xue et al., 2023). At the same time, genotype-focused greenhouse screening showed that high temperature depressed photosynthesis, chlorophyll, proline balance, and vegetative traits such as plant height and shoot and root fresh weight, confirming that the value of temperature regulation depends partly on cultivar heat tolerance (Rajametov et al., 2021).

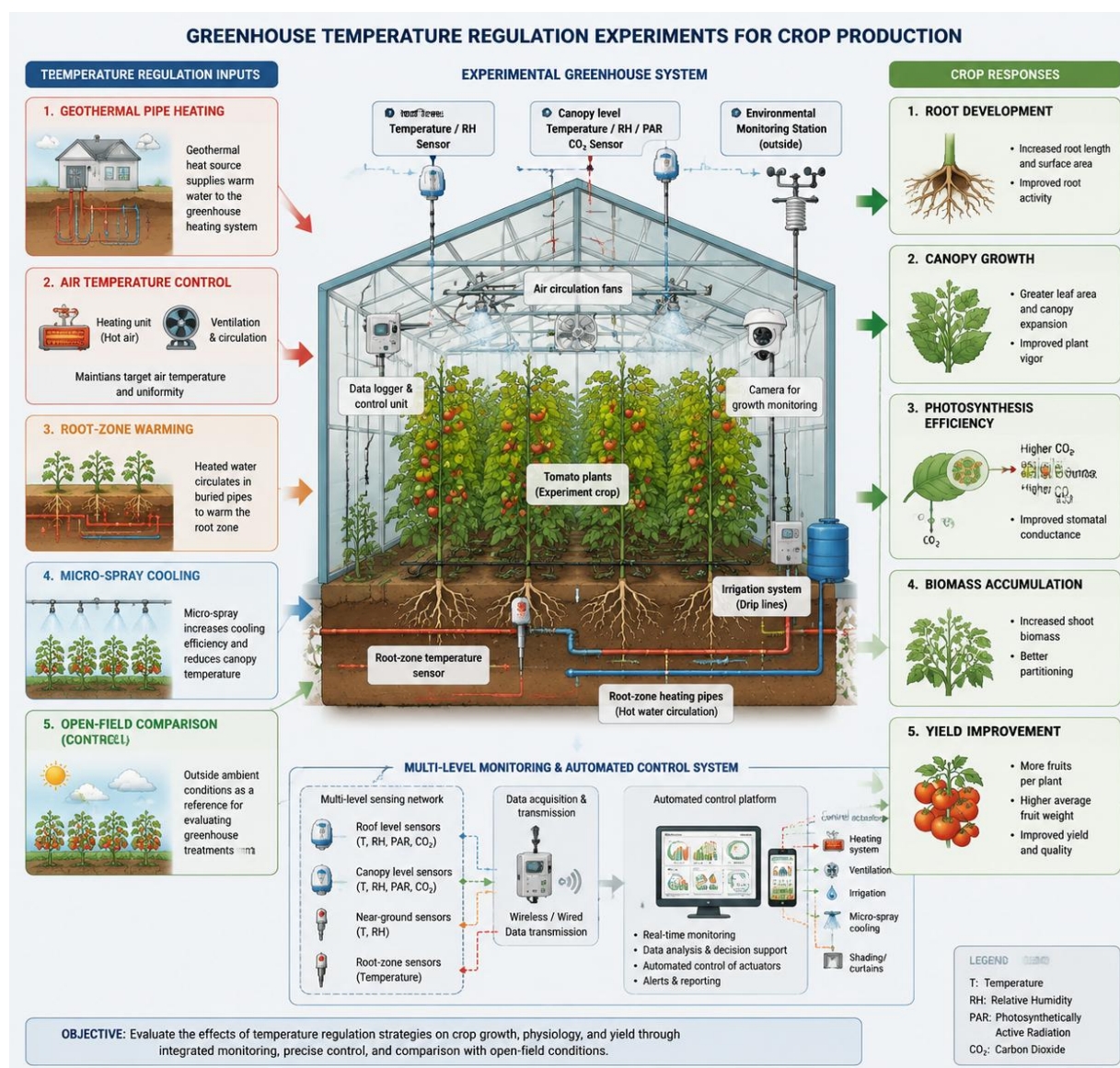


Figure 2 Experimental framework for evaluating greenhouse temperature regulation strategies and their effects on crop growth performance

7.3 Effects on yield performance and economic benefits

The yield effects of greenhouse temperature regulation were substantial, but they depended on how effectively the strategy stabilized the crop microclimate. In a greenhouse versus open-field comparison, weekly temperature variation was only about $\pm 1.0^{\circ}\text{C}$ in the greenhouse versus $\pm 10.2^{\circ}\text{C}$ in the open field, and the more stable greenhouse environment produced higher yields while reducing the risk of total crop loss (Efeta et al., 2025). In another greenhouse study, passive solar protection increased marketable tomato yield by 1.8-fold over open-field production, although adding shade delayed flowering and reduced marketable yield by 48%, showing that not every cooling-oriented intervention improves productivity (Angmo et al., 2021).

More intensive regulation strategies also translated into measurable yield and economic gains. Geothermal soil warming increased yield by about 18.2%-18.6% and water productivity by 32.6%-33.5%, with optimal soil temperatures estimated at 26.1°C in spring/summer and 20.6°C in autumn/winter (Ouyang et al., 2022). Economic