Smart Greenhouse Sensor References

Academic References for Tomato Cultivation Environmental Parameters

Project Overview

Smart Greenhouse Control System for Elderly Farmers

This simulation-based smart greenhouse system implements realistic environmental sensor values specifically calibrated for optimal tomato cultivation. All sensor ranges and parameters are based on peer-reviewed academic research and industry standards for greenhouse tomato production.

Temperature Control
22-28°C (Day) / 16-20°C (Night)

Humidity Management
60-80% (Day) / 65-85% (Night)

Light Intensity
20,000-50,000 lux (Day)

CO_2 Monitoring
350-800 ppm (Day)

pH Control
6.0-6.8 (Optimal)

Soil Moisture
40-60% (Optimal)

Implemented Sensor Parameters

Temperature Sensor

Day: 22-28°C | Night: 16-20°C

Optimal temperature ranges for tomato photosynthesis and growth. Day temperatures support active metabolism while cooler night temperatures promote fruit development.

Humidity Sensor

Day: 60-80% | Night: 65-85%

Relative humidity levels that prevent disease while maintaining optimal transpiration rates and stomatal function in tomato plants.

Soil Moisture Sensor

Optimal: 40-60%

Soil moisture levels that ensure adequate water availability while preventing root rot and maintaining proper nutrient uptake in tomato plants.

Light Intensity Sensor

Day: 20,000-50,000 lux | Night: 10-50 lux

Light intensity levels that maximize photosynthetic efficiency while preventing photo-inhibition in greenhouse tomato cultivation.

CO_2 Sensor

Day: 350-800 ppm | Night: 300-500 ppm

Carbon dioxide concentrations that enhance photosynthetic rates during daylight hours while maintaining normal respiration at night.

pH Sensor

Range: 5.5-7.5 | Optimal: 6.0-6.8

Soil pH levels that optimize nutrient availability and uptake, particularly for essential elements like nitrogen, phosphorus, and potassium.

Nutrient Sensor

Optimal: 70-90%

Nutrient concentration levels that support vigorous growth and high-quality fruit production in hydroponic and soil-based tomato systems.

Primary Academic Reference

> **Shamshiri, R. R., Jones, J. W., Thorp, K. R., Ahmad, D., Man, H. C., & Taheri, S.** *Review of optimum temperature, humidity, and vapour pressure deficit for microclimate evaluation and control in greenhouse cultivation of tomato: a review* International agrophysics, 32(2), 161-170. (2018)
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> **Note:** This comprehensive review provides the foundational parameters for most of the environmental ranges implemented in our simulation. It synthesizes decades of research on optimal tomato growing conditions.

Supporting Academic References

Temperature Control References

De Koning, A. N. M. *Development and dry matter distribution in glasshouse tomato: a quantitative approach* Wageningen University and Research. (1994)

Heuvelink, E. *Tomatoes* CABI Publishing, Wallingford, UK. (2005)

Humidity Control References

Bakker, J. C. *Effects of humidity on stomatal density and its relation to leaf conductance in cucumber* Scientia Horticulturae, 48(3-4), 205-212. (1991)

Willits, D. H. *Constraints and limitations in greenhouse cooling: challenges in next-generation CEA* Acta Horticulturae, 614, 265-272. (2003)

CO_2 Management References

Mortensen, L. M. *Review: CO_2 enrichment in greenhouses. Crop responses* Scientia Horticulturae, 33(1-2), 1-25. (1987)

Hicklenton, P. R., & Jolliffe, P. A. *Alterations in the compensation points of cucumber, tomato, and lettuce plants after prolonged exposure to different CO_2 concentrations* Canadian Journal of Botany, 58(20), 2181-2187. (1980)

Light Intensity References

Heuvelink, E., & Dorais, M. *Crop growth and yield. In Tomatoes (pp. 85-144)* CABI Publishing. (2005)

McAvoy, R. J., & Janes, H. W. *Tomato plant response to low light stress and the relationship between low light tolerance and yield* Journal of the American Society for Horticultural Science, 109(6), 808-812. (1984)

pH and Nutrient Management References

Adams, P. *Nutritional control in hydroponics. In Hydroponic Production of Vegetables and Ornamentals (pp. 211-261)* Embryo Publications. (2002)

Jones Jr, J. B. *Hydroponics: a practical guide for the soilless grower* CRC Press. (2005)

Sonneveld, C., & Voogt, W. *Plant nutrition of greenhouse crops* Springer Science & Business Media. (2009)

Irrigation and Soil Moisture References

Taylor, M. D., Locascio, S. J., & Alligood, M. R. *Blossom-end rot incidence of tomato as affected by irrigation quantity, calcium source, and reduced potassium* HortScience, 39(5), 1110-1115. (2004)

Zotarelli, L., Dukes, M. D., Scholberg, J. M., et al. *Nitrogen and water use efficiency of zucchini squash for a plastic mulch bed system on a sandy soil* Scientia Horticulturae, 116(1), 8-16. (2008)

Implementation Methodology

Sensor Simulation Approach:

Each sensor class in our simulation implements realistic fluctuation patterns based on the referenced academic parameters. The sensors include:

- **TemperatureSensor** - Implements day/night temperature cycles
- **HumiditySensor** - Simulates humidity variations with weather patterns
- **SoilMoistureSensor** - Models moisture depletion and irrigation effects
- **LightSensor** - Reproduces natural and artificial lighting conditions
- **CO2Sensor** - Simulates CO_2 fluctuations during photosynthesis cycles
- **PHSensor** - Models pH stability with nutrient management effects
- **NutrientSensor** - Tracks nutrient depletion and replenishment

Validation Approach:

All sensor ranges were validated against multiple academic sources to ensure scientific accuracy. The simulation maintains realistic fluctuation patterns while staying within optimal ranges for tomato cultivation.

Additional Academic Resources

Van Straten, G., Van Willigenburg, G., Van Henten, E., & Van Ooteghem, R. *Optimal control of greenhouse cultivation* CRC Press. (2010)

Körner, O., & Challa, H. *Design for an improved temperature integration concept in greenhouse cultivation* Computers and Electronics in Agriculture, 39(1), 39-59. (2003)

Zhang, N., Wang, M., & Wang, N. *Precision agriculture—a worldwide overview* Computers and Electronics in Agriculture, 36(2-3), 113-132. (2002)

How to Cite This Work

Academic Citation Format:

"The environmental sensor values implemented in this Smart Greenhouse simulation are based on established optimal ranges for tomato cultivation in controlled environments. Temperature ranges of 22-28°C during day and 16-20°C during night follow recommendations by Shamshiri et al. (2018) and De Koning (1994). Humidity levels of 60-80% during day and 65-85% during night are consistent with findings by Bakker (1991) and Willits (2003). CO_2 *enrichment levels of 350-800 ppm during daylight hours align with research by Mortensen (1987) and Hicklenton & Jolliffe (1980)."*