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Root Zone Heating for Greenhouse Crops

Current Topic

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Root-zone heating is a greenhouse production method that focuses on an optimum root temperature by distributing heat to bench and floor growing systems. It is an appropriate technology in the sense that it promotes energy conservation in modern greenhouse production. To warm roots, hot water is distributed through EPDM rubber tubing (also known as hydronic thermal tubing) or PVC piping laid out in a looping pattern. Though modern greenhouses typically use natural gas or fuel oil to heat water, alternative energy sources include geothermal, solar, wood, thermal biomass (heat from compost or brushwood piles), and co-generation. The benefits to plant growth from root-zone heating systems are well documented.

Energy savings are a distinct advantage. Simply put, research has shown that root zone temperatures are more critical to plant growth than leaf temperatures. By maintaining an optimum root zone temperature, greenhouse air temperatures can be lowered 15° F. Researchers in California determined that bench-top heating systems used only half the energy required by a perimeter hot water system to produce chrysanthemum and tomato crops (1).

Floor heating is ideal for crops grown directly on the floor—such as bedding plants, containerized ornamentals, and bag-cultured vegetables—as well as greenhouse vegetables grown directly in the soil. With a cool-season crop (lettuce, spinach, Asian leaf vegetables), supplemental air heating may not even be required in a floor-heated greenhouse. A typical temperature pattern for a two-foot-tall crop in February with an outside temperature of 10° F would be a floor temperature of 74° F, a canopy temperature of 55° F, and a temperature of 48° F four feet above the ground (2).

High-temperature EPDM tubing was a revolutionary achievement in the development of floor-heating systems, and in addition to its use in greenhouses, hydronic tubing has spurred the adoption of radiant floor heating in homes and office buildings. Prior to EPDM tubing, greenhouses were fitted with permanent floor-heating systems featuring PVC piping buried in the floor biomass. While PVC piping is low-tech in comparison to hydronic tubing, this system design is still employed in many greenhouses today. Regardless, tubes or pipes are usually laid out on 12" to 18" centers, embedded in porous concrete, gravel, or sand. Hot water—from gas water heaters or from an alternative fuel source such as solar hot water collectors located outside the greenhouse—is circulated through the pipes, warming the greenhouse floor.

Rutgers University initiated research into soil heating systems in the mid-1970s. S*oil Heating Systems for Greenhouses Production*, a 16-page leaflet from Rutgers Cooperative Extension, is enclosed for your information. It provides a summary of floor heating systems; materials that can be used for piping; system design; floor construction; warm water supply; environmental control; and bench heating options.

In the year 2000, the Horticultural Engineering program at Rutgers University was recognized by ASAE—American Society of Agricultural Engineers—as one of the five outstanding achievements in agricultural engineering for the 20th century (3).

> Three concepts have been integrated to develop low-cost greenhouse structures and environmental control systems that require little energy for winter heating relative to classical systems: [1] the air-inflated double-layer polyethylene greenhouse; [2] movable thermal insulation for greenhouses; and [3] root-zone heating systems for production greenhouses.

As a note of interest, the Department of Bioresource Engineering at Cook College, Rutgers University (famous for these innovative greenhouse engineering achievements such as floor heating) ceased to exist in the year 2000, primarily due to retirements among its faculty. The remaining faculty, as well as the horticultural engineering program, are now part of the Department of Plant Biology and Pathology at Cook College, Rutgers University (4). Of special interest are the web archives for the *Horticultural Engineering* newsletter and the *CCEA Newsletter* (5).

Root-zone heating systems work well with any low-temperature (90–110° F) hot water system. Possibilities include geothermal water, waste water from power plants and cogeneration facilities, and solar- or compost-heated water.

In addition to this resource packet on root-zone heating, there are two related ATTRA publications on the topic of greenhouse heating:

- *Solar Greenhouses: A Resource List*
- *Compost Heated Greenhouses*

The enclosed items provide further details and resources on root-zone heating. Of special interest is the informative summary by John W. Bartok, Jr., "Designing a Root Zone Heating System," in the *Connecticut Greenhouse Newsletter*.

For suppliers of tubing, radiant heat tape, and related root-zone heating equipment, see the enclosed article from *Greenhouse Management & Production*, "A Look at: Root Zone Heating." For a comprehensive list of products and suppliers that support the nursery and greenhouse industries, see The Green Beam website; it will include updated contact information for the companies listed in the aforementioned article.

The Green Beam
http://www.greenbeam.com

The Green Beam website is maintained by Branch-Smith Publishing—publisher of *NMPro*, *GMPro*, *Garden Center Merchandising and Management*, and *Garden Center Products and Supplies*. It is an online version of the comprehensive Buyer's Guide Directory published in these trade magazines.

References

1) Sachs, R.M. et al. 1992. Plant response and energy savings for bench-top heated greenhouses. Scientia Horticulturae. Vol. 49, No. 1–2. p. 135–146.

2) Whitcomb, Carl E., Charlie Gray, and Billy Cavanaugh. 1985. A floor heating top ventilating system for quonset greenhouses. p. 4–10. In: Nursery Research Field Day. Research Report P-872. Agricultural Experiment Station, Oklahoma State University.

3) CCEA Newsletter. 2000. Outstanding agricultural achievement of the 20th century. The Center for Controlled Environment Agriculture, Rutgers University. Vol. 9, No. 3 & 4.

4) Department of Plant Biology and Pathology
Cook College Campus, Rutgers University
20 Ag Extension Way
New Brunswick, NJ 08901-8500
732-932-9753

Note: A related publication from Rutgers University is *Environmental Control of Greenhouses*, Publication E-213. Contact the Department of Plant Biology and Pathology to obtain a copy.

5) Horticultural Engineering Websites at Cook College, Rutgers University:

The Center of Excellence for Controlled Environment Agriculture, Rutgers University
http://AESOP.RUTGERS.EDU/~ccea/

Horticultural Engineering, Rutgers University
http://aesop.rutgers.edu/~horteng/

Horticultural Engineering Newsletters, Rutgers University
http://aesop.rutgers.edu/~horteng/newsletter.htm
- *Horticultural Engineering*
- *CCEA Newsletter* —Center for Controlled Environment Agriculture

Enclosures

Bartok, John W., Jr. 1994. Designing a root zone heating system. Connecticut Greenhouse Newsletter. December 1994–January 1995. No. 183. p. 11–17.

Bartok, John W., Jr. 1995. Root zone heating options. Greenhouse Management & Production. August. p. 80–81.

Brugger, Michael, and Randall Zondag. 1989. Be astute—heat your roots. Greenhouse Grower. December. p. 28, 31.

Hopkins, Matthew T. 1994. The bottom line on heating. Greenhouse Grower. December. p. 26, 28, 30.

McLean, Jennifer. 1995. A look at: Root zone heating. Greenhouse Management & Production. August. p. 53–54, 59.

Pyle, Kathleen. 1994. Revisiting root zone heating. GrowerTalks. April. p. 22, 24, 26.

Roberts, William J. 1996. Soil Heating Systems for Greenhouse Production. Rutgers University Cooperative Extension, E-208. 16 p.

Further Reading

This Further Reading section contains literature citations to additional articles and experiment station bulletin reports we have identified through research. They are listed here for reference, in case you wish to follow this topic in more detail. A local librarian can help you obtain photocopies of agricultural literature through the Inter-Library Loan program.

Bartok, J.W. and R.A. Aldrich. 1984. Low cost solar collectors for greenhouse water heating. Acta Horticulturae. Vol. 148. p. 771–774.

Brugger, M.F. 1984. Some applications of floor heating in commercial Ohio greenhouses. Acta Horticulturae. Vol. 148. p. 115–118.

Elston, Rob. 1991. A look at: Root-zone heating systems. Greenhouse Manager. December. p. 83–84.

Gent, Martin and Vincent Malerba. 1994. Soil heating made simple. American Vegetable Grower. August. p. 38–39.

Roberts, Bill. 1991. Soil heating improves transplant production. American Vegetable Grower. November. p. 40–42.

Roberts, W.J. et al. 1985. Energy Conservation for Commercial Greenhouses. NRAES–3. Northeast Regional Agricultural Engineering Service, Cornell University. p. 27-30.

Whitcomb, Carl E., Charlie Gray, and Billy Cavanaugh. 1984. The "ideal" greenhouse for propagation. p. 4–8. In: Nursery Research Field Day. Research Report P–855. Agricultural Experiment Station, Oklahoma State University.

Whitcomb, Carl E., Charlie Gray, and Billy Cavanaugh. 1985. A floor heating top ventilating system for quonset greenhouses. p. 4–10. In: Nursery Research Field Day. Research Report P-872. Agricultural Experiment Station, Oklahoma State University.

Web Resources

Greenhouse Condensation Control: Bottom Heating and Between-row Heating
Ohio State University
http://ohioline.osu.edu/aex-fact/0801.html

Radiant Floor Heating Systems Can Be Used for Greenhouses
http://www.radiant-concepts.com/applications/greenhouses.html
Case study of Lowe's Greenhouse in Chagrin Falls, Ohio regarding the Wirsbo Radiant Floor Heating system.

Hydronic Heating System at Solar Haven
http://www.solarhaven.org/Hydronic.htm
Case study of greenhouse in Tucson, Arizona integrating solar hot water collectors with hydronic floor heating.

Midwest Renewable Energy Association
http://www.the-mrea.org

Just the Facts! – Solar Hydronic Radiant Floor Heating System Basics
http://www.the-mrea.org/justthefacts.htm#Collectors1

Solar Hydronic Radiant Floor Heating Systems – Fact Sheet
http://www.the-mrea.org/download/HydronicFloorsFactSheet.pdf

Solar Radiant Floor Heating
Energy Efficiency and Renewable Energy Clearinghouse (EREC)
http://www.eren.doe.gov/consumerinfo/refbriefs/ad8.html

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The Electronic version of **Root Zone Heating for Greenhouse Crops** is located at:
HTML
http://www.attra.org/attra-pub/ghrootzone.html
PDF
http://www.attra.org/attra-pub/PDF/ghrootzone.pdf