title	Simulated Effects of Reflective Mulch on Energy and Water Consumption in Open and Closed Greenhouse Systems in Semi-Arid Regions
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proj_desc	SummaryThe California greenhouse industry is the largest in the U.S. The area under glass, plastic or other protection in California reached over 5,000 acres accounting over 20% of all U.S. greenhouses (USDA, 2002). One major factor hindering future expansion of this industry is the cost required to provide environmental control. Large energy costs are frequently incurred to maintain the required thermal and radiant environments in greenhouses during both winter and summer seasons. Greenhouses in hot and arid regions also require large quantities of water for irrigation. Consequently, considerable effort is expended for energy and water conservation. This study aims to focus on reducing natural gas, electricity, and water consumption in open and closed greenhouse systems in semi-arid regions by manipulating the radiant and thermal environments in greenhouses. The closed system has no external aeration and has no need for further water supply. It has a great potential to reduce the demand for natural gas, the load on the power grid, and the demand for irrigation water in greenhouse operations. It also allows plant protection without chemical insecticides and the fixation of carbon dioxide without aeration losses. In addition, reflective mulch will be used to cover the greenhouse floor in order to change both radiant and thermal environments within. It is expected that both water and energy consumptions will vary as a result of mulch application in both open and closed greenhouse environments. Simulation results will help us to properly manage the internal environment and develop better control strategies for enhanced energy and water conservation.1. Background and Problem StatementGreenhouses provide a suitable environment for the intensive production of a variety of crops. They are designed to provide control of solar radiation, temperature, humidity, and CO2 (carbon dioxide) levels in the aerial environment; and in hydroponic systems, nutrient levels and root temperatures can also be controlled. The greenhouse industry has a significant impact on the dynamics of modern agricultural business in California. The California greenhouse industry is the largest in the U.S. with an area under glass, plastic or other protection over 5,000 acres accounting over 20% of all U.S. greenhouses (USDA, 2002). California's Gross Cash Income from the greenhouse, nursery and floriculture industry reached 3.3 billion dollars (California Department of Food and Agriculture, 2005). Total greenhouse operations in 2002 were reported to be 2,129 providing thousands of full- and part-time employment opportunities in California (USDA, 2002). One major factor hindering future expansion of this industry, however, is the cost required to provide proper environmental control. Large energy costs are frequently incurred to maintain the required thermal and radiant environments in greenhouses during both winter and summer seasons. During the winter season, supplemental heat is needed at night, and it may be needed during the day as well. Due to high solar radiation loads, cooling must be provided to maintain an appropriate environment during warm weather. High temperatures and solar loads limit the length of the production cycle especially in summer. If cooling could be provided at a reasonable cost during these periods, the production cycle could be extended for selected, high-value crops. Greenhouses in hot and arid regions also require large quantities of water for irrigation. Consequently, considerable effort is expended for energy and water conservation.2. Scientific and Technological BaselineTo provide economically optimal micro-environments for plant growth, producers can use or control the number of glazing layers, insulation curtains or screens to reduce long-wave radiation losses at night, reduced ventilation rates, evaporative coolers, and shading devices to control incoming solar radiation. In addition, heat pump systems may also be used for reducing primary energy use for winter heating requirements and warm weather cooling loads.While lower ventilation rates reduce the heating requirements, they may cause high relative humidity levels in greenhouses and low CO2 levels if CO2 enrichment is not provided. Consequently, low ventilation rates may adversely affect plant responses. If conventional ventilation rates are used to maintain reasonable relative humidity levels within greenhouses, they result in higher primary energy requirements (high operating costs). Similarly, installation of curtains or shading screens reduce long-wave radiation losses at night and warm weather cooling

requirements during the day; however, it would increase the initial cost of the overall system. The use of reflective mulch, on the other hand, increases light absorption and thus assimilation by the crop, particularly at the young stage of crop development. However, mulch application may have different consequences depending on the mulch's reflectivity. These consequences include the change in energy and water requirements.Greenhouses in hot and arid regions require large quantities of water for irrigation. As mentioned above, during the summer months, inside temperatures rise above the acceptable limits so the greenhouses become unusable during this period. Being biological air-conditioners, plants consume large amounts of water to provide comfortable microenvironments for survival.A dynamic simulation model was developed and validated to provide an accurate prediction of greenhouse energy and moisture exchanges as a function of dynamic environmental factors such as solar energy, outside temperatures and moisture levels, auxiliary heating, plant moisture and energy exchanges and excess heat removal or storage (Yildiz and Stombaugh, 2006b). This dynamic prediction model was developed from basic energy, mass conservation and heat transfer principles for greenhouses having single or double plastic glazing. The model also incorporated a dynamic simulation of cucumber growth. This model will be used to predict heating and cooling loads, water use, CO2 use and fixation, and to evaluate the operational strategies associated with heating and cooling using the proposed reflective mulch in greenhouses in semi-arid regions. The reflective mulch will be evaluated for both open and closed systems.3. Project Goal and ObjectivesThe main goals of the proposed project are to reduce the demand for natural gas, the load on power grid, and the large demand for irrigation water in greenhouse operations. The specific objective of this study is to compare open and closed greenhouse systems with and without reflective mulch in terms of energy and water consumption in semi-arid regions.4. Milestones and Deliverablesa) Local Weather Data Collection: Data collection will resume early February 2008. Due: February 28, 2008b) Virtual Greenhouse System Design and Model Modifications: Complete virtual greenhouse system will be designed, and proper model modifications will be made. Due: April 30, 2008.c) Simulations: Simulation studies will be completed and the simulation results will be delivered. Due: June 30, 2008.d) Data Analyses and Final Report: Simulation results will be scientifically analyzed and a final report will be prepared and delivered. Due: September 30, 2008.e) Conference Presentation and Publication: Simulation results will be scientifically analyzed, presented and published at ISHS International Workshop on Greenhouse Environmental Control and Crop Production in Semi-Arid Regions, Tucson, AZ. Due: October 20-24, 2008.5. Team Qualifications and Project Resourcesa) Dr. Ilhami Yildiz is a faculty member at California Polytechnic State University, BioResource and Agricultural Engineering Department. He has been working on the microclimate modification systems in both enclosed and open agro-ecosystems for almost 20 years, and has developed several energy and water conserving greenhouse systems, and operational and control strategies for both open and enclosed agro-ecosystems. His research findings and expertise have been utilized in various national and international greenhouse projects. Some of his recent relevant publications were listed in Section 6. He has also worked in the North American commercial greenhouse industry for many years, and has designed a number of commercial heating and cooling systems transferring extensive research findings to commercial operations in Canada and the United States.b) Dr. Shikha Rahman is a faculty member at California Polytechnic State University, Civil and Environmental Engineering Department. She has many years of experience in water resources engineering and numerical modeling. Her specialties include hydrological processes, environmental and experimental fluid mechanics, graphics and 3D visualization techniques, numerical modeling and optimization techniques, plume tracking by aquatic organisms. Some of her relevant publications were listed in Section 6.c) Two Honors Students – To be determined.6. ReferencesYildiz, I. and Stombaugh, D.P. (2007). Simulated effects of canopy size, relative humidity and light management levels, CO2 dosing, and minimum ventilation rates on energy consumption in open and confined greenhouse systems. Oral Presentation, GreenSYS 2007, Naples, Italy, October 4-6, 2007Yildiz, I. and Stombaugh, D.P. (2007). Simulated effects of canopy size, relative humidity and light management levels, CO2 dosing, and minimum ventilation rates on water consumption in open and confined greenhouse systems. Poster Presentation, GreenSYS 2007, Naples, Italy, October 4-6, 2007Yildiz, I. and Stombaugh, D.P. (2007). Simulated effects of canopy size, relative humidity and light management levels, CO2 dosing, and minimum ventilation rates on energy consumption in open and confined greenhouse systems. Book of Abstracts, GreenSYS 2007, High Technology for Greenhouse System Management, Naples, Italy, October 4-6, 2007, 135-136Yildiz, I. and Stombaugh, D.P. (2007).

	Simulated effects of canopy size, relative humidity and light management levels, CO2 dosing, and minimum ventilation rates on water consumption in open and confined greenhouse systems. Book of Abstracts, GreenSYS 2007, High Technology for Greenhouse System Management, Naples, Italy, October 4-6, 2007, 85-86Yildiz, I. and Stombaugh, D.P. (2006). Heat pump cooling and greenhouse microclimates in open and confined greenhouse systems. Acta Hort. (ISHS) 719:255-262Yildiz, I. and Stombaugh, D.P. (2006). Heat pump cooling and greenhouse microclimates in open and confined greenhouse systems. Book of Abstracts. Int. Symposium on Greenhouse Cooling: Methods, Techniques and Plant Response. April 24-27, 2006. Almeria, Spain, 41Yildiz, I. and Stombaugh, D.P. (2006). Dynamic modeling of microclimate and environmental control strategies in a greenhouse coupled with a heat pump system. Acta Hort. (ISHS) 718:331-340Yildiz, I. and Stombaugh, D.P. (2006). Simulated performances of a heat pump system for energy and water conservation in open and confined greenhouse systems. Acta Hort. (ISHS) 718:341-350Jackson, J.L., D.R. Webster S. Rahman, and M.J. Weissburg, (2007). Bed-roughness effects on boundary layer turbulence and consequences for odor tracking behavior of blue crabs (Callinectes sapidus). Limnology and Oceanography, Vol. 52, No. 5Weissburg, M.J., J.L. Jackson, S. Rahman, and D.R. Webster, (2007). The Effects of Vertical Odor Plume Structure on Navigation and Foraging Performance in Blue Crabs. 2007 Annual Meeting of the Society for Integrative and Comparative Biology, Phoenix, AZRahman, S. and D.R. Webster, (2005). Effect of bed roughness on scalar fluctuations in turbulent boundary layers. Experiments in Fluids, Vol. 38, No.2Jackson, J., S. Rahman, D.R. Webster, and M.J. Weissburg, (2007). Effect of Bed Roughness on Scalar Mixing and Odor Plume Navigation in Turbulent Boundary Layer Flows. 2004 ASLO Ocean Research Conference, Honolulu, HIAmini, F., T. L. Biddlecom, S. Rahman and M. K. Sharpe, (2004). Soil Liquefaction at Depth Scientific Visualization. International Conference on Environmental Modeling and Simulation (IASTED), St. Thomas, US Virgin Islands
inter_desc	It is our hope that future honors program students will be versed in not only the simulation aspects of controlled environments (biological and physical), but also the water and energy conserving technologies. Thus students working with the professors in this proposal will be exposed to both mathematical simulation techniques, and conserving water and energy resources operating highly specialized virtual greenhouses.
links	None
students	2
majors	BRAE, CE, ENVE, HCS, ME
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