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Clara Gattuso

Department of Agricultural,
Food and Environmental
Sciences, University of
Perugia, Perugia, Italy

Anna Mazzola

Department of Agricultural,
Food and Environmental
Sciences, University of
Perugia, Perugia, Italy

Corresponding Author:

Clara Gattuso

Department of Agricultural,
Food and Environmental
Sciences, University of
Perugia, Perugia, Italy

Technology of diffuse covering materials for greenhouses

Clara Gattuso and Anna Mazzola

Abstract

The utilization of diffuse covering materials in greenhouse agriculture represents a pivotal advancement in optimizing light distribution, enhancing plant growth, and improving energy efficiency. This paper delves into the technological innovations surrounding diffuse covering materials, assessing their impact on spectral light quality, microclimate regulation, and overall plant physiology within greenhouse environments. By systematically reviewing and comparing the performance of various materials such as polycarbonate sheets, ethylene-vinyl acetate (EVA) films, and diffuse glass, this study aims to provide comprehensive insights into the selection and application of these materials to maximize agricultural productivity. Through empirical research and comparative analysis, the paper highlights the significance of diffuse light in reducing plant stress, improving photosynthetic efficiency, and ensuring uniform crop development, thereby underscoring the potential of these technologies in advancing sustainable greenhouse farming practices.

Keywords: Greenhouses, energy, ethylene-vinyl acetate, photosynthetic

Introduction

The quest for efficiency in greenhouse agriculture has led to significant technological advancements aimed at optimizing environmental conditions, thereby enhancing plant health and productivity. Among these innovations, the development and application of diffuse covering materials stand out as a critical component in creating ideal growing environments. Unlike traditional transparent coverings that allow direct sunlight penetration, resulting in hotspots and uneven light distribution, diffuse materials scatter sunlight, ensuring a uniform distribution of light across the plant canopy. This uniformity is crucial for the photosynthetic efficiency of lower leaves and the overall growth and development of the plants.

The significance of diffuse covering materials extends beyond light distribution. These materials play a vital role in regulating the microclimate within greenhouses, affecting temperature, humidity, and even pest dynamics. Furthermore, they contribute to energy conservation by reducing the need for artificial lighting and cooling systems, thereby aligning with sustainable agricultural practices.

However, the adoption of diffuse covering materials is not without its challenges. Factors such as material longevity, cost, and the specific light transmission requirements of different plant species necessitate a comprehensive understanding of these technologies. This paper aims to bridge this knowledge gap by exploring the technological underpinnings of diffuse covering materials for greenhouses, examining their effects on plant growth and environmental efficiency, and providing actionable insights for their application in modern agriculture.

Through an exploration of the material science behind greenhouse coverings, an analysis of their impact on plant physiology, and a review of their practical applications, this study seeks to underscore the potential of diffuse covering materials to revolutionize greenhouse agriculture. By offering a detailed comparison of the available materials and their respective advantages and limitations, the paper endeavours to guide agricultural practitioners in making informed decisions that enhance productivity and sustainability in greenhouse farming.

Objective of study: The primary objective of this study is to evaluate the effectiveness of various diffuse covering materials in enhancing the spectral quality and distribution of light within greenhouses, and to assess their impact on the growth, health, and yield of selected crop species.

Materials

- **Diffuse Covering Materials:** Polycarbonate sheets, diffuse glass, and ethylene-vinyl acetate (EVA) films.
- **Control Material:** Clear plastic or glass for comparison.
- **Plant Species:** Common greenhouse crops (tomatoes, lettuce).
- **Measurement Tools:** Sensors for light, temperature, humidity, and CO₂ levels.

Methods

1. **Experimental Setup:** Controlled greenhouse sections each covered with different diffuse materials versus a control.
2. **Light Analysis:** Measurement of light intensity and distribution using sensors.
3. **Plant Monitoring:** Growth, photosynthesis rates, and yield recorded for comparison.
4. **Environmental Monitoring:** Continuous tracking of temperature, humidity, and CO₂ levels.

Use of Material Engineering in Diffuse Covering Materials for Greenhouses

Material engineering plays a pivotal role in the development and optimization of diffuse covering materials for greenhouses, focusing on enhancing the performance and sustainability of these materials.

Innovative Materials: Material engineers research and develop new materials that offer superior light diffusion, durability, and energy efficiency. This includes polymers, glasses, and composites designed to scatter light evenly within the greenhouse, enhancing plant growth while minimizing heat build-up.

Material Properties Optimization: Through the manipulation of chemical compositions and physical structures, material engineers optimize properties such as light transmission, diffusion coefficient, UV resistance, and longevity of the covering materials. This ensures that the materials not only provide optimal growing conditions but also withstand environmental factors like UV radiation, temperature variations, and physical wear over time.

Functional Coatings: The application of coatings to greenhouse coverings that improve their functionality, such as anti-reflective, anti-condensation, and UV protective coatings. These treatments enhance the performance of diffuse covering materials by increasing light transmission, reducing water droplet formation that can block light, and

protecting plants from harmful UV rays.

Surface Engineering: Engineering the surface properties of covering materials to achieve desired levels of diffusion and to control the spectral quality of light entering the greenhouse. Surface texturing techniques, for example, can be used to modify the interaction of light with the material surface, improving light scattering and uniformity.

Eco-friendly Materials: Developing materials that are not only effective in their function but also environmentally friendly. This includes sourcing sustainable raw materials, designing for recyclability, and reducing the carbon footprint associated with the production and disposal of covering materials.

Energy Efficiency: Material engineers work on creating materials that contribute to the overall energy efficiency of greenhouses. This involves optimizing the thermal properties of covering materials to reduce the need for additional heating or cooling, thereby lowering energy consumption and operational costs.

Durability Testing: Conducting rigorous tests to evaluate the durability and performance of diffuse covering materials under various environmental conditions. This ensures that the materials can maintain their optical and mechanical properties over time, providing long-term reliability and reducing the need for frequent replacements.

Light Distribution Analysis: Utilizing advanced modeling and simulation tools to analyze the light distribution properties of different materials. Material engineers study how light interacts with these materials to ensure that the diffusion effect meets the specific requirements for optimal plant growth.

Interdisciplinary Research: Material engineers often collaborate with horticultural scientists to understand the specific light requirements of different plant species. This collaborative approach ensures that the development of diffuse covering materials is aligned with the goals of maximizing crop yield and quality.

In summary, material engineering is central to advancing the technology of diffuse covering materials for greenhouses. Through the development of innovative materials, application of functional coatings, focus on sustainability, and rigorous performance testing, material engineers contribute to the creation of greenhouse environments that are conducive to efficient plant growth and sustainable agricultural practices.

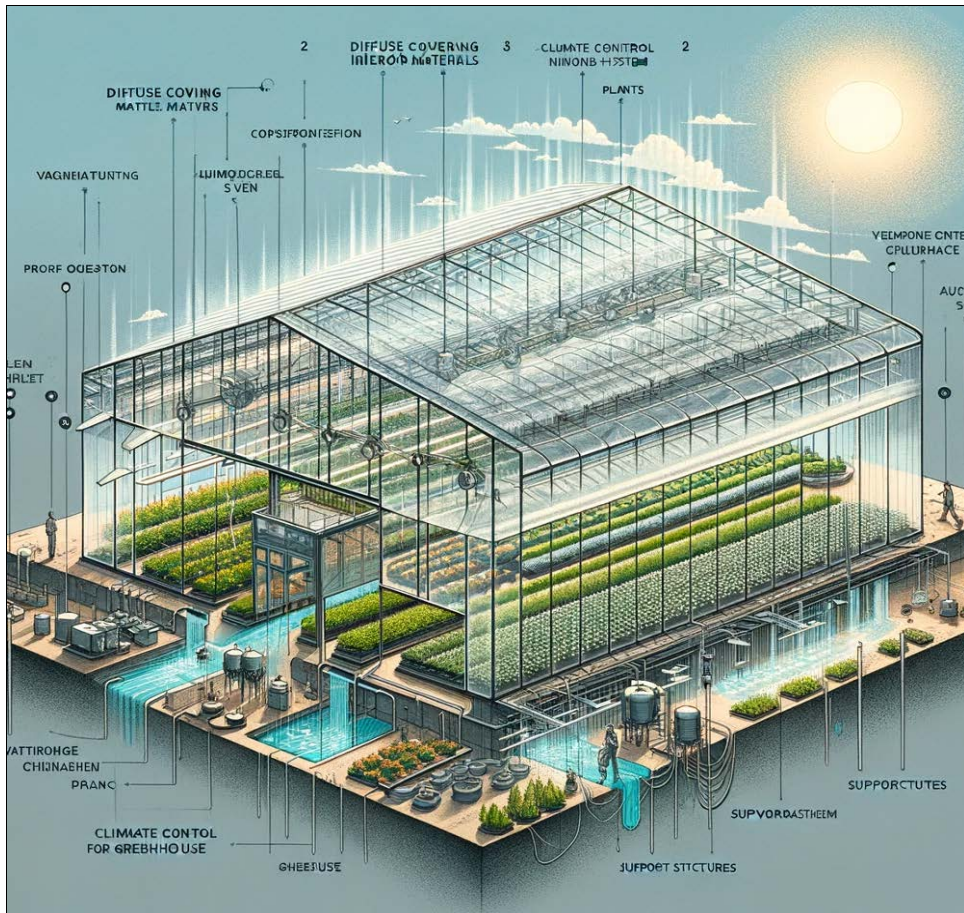


Fig. 1: Diffuse Covering Materials for Greenhouses



Fig. 2: Modern agricultural practices with greenhouse environment

The technology of diffuse covering materials for greenhouses components and equipment designed to optimize light distribution, enhance plant growth, and improve overall greenhouse efficiency.

1. Diffuse Covering Materials: The core of this technology, these materials are used as the greenhouse's outer layer to scatter sunlight evenly throughout the interior. Common materials include:

- **Diffuse Glass:** Glass with a surface treatment or embedded particles that scatter incoming light.
- **Polycarbonate Sheets:** Lightweight, durable plastic sheets with inherent or coated diffusion properties.
- **Acrylic Sheets:** Similar to polycarbonate but with different optical and physical characteristics.
- **Ethylene Vinyl Acetate (EVA) Films:** Plastic films used for their flexibility, clarity, and diffusion capabilities.

2. Support Structures: The frame that holds the covering materials in place, typically made from:

- **Steel:** For its strength and durability.
- **Aluminum:** Preferred for its lightweight and resistance to corrosion.
- **Wood or Bamboo:** Used in certain regions for its availability and sustainability.

3. Automated Irrigation Systems: Designed to efficiently water plants based on specific needs and environmental conditions, they can include:

- **Drip Irrigation:** Delivers water directly to the base of each plant, reducing waste.
- **Misting Systems:** Provide a fine spray of water, useful for humidity control and cooling.

4. Climate Control Sensors: Monitor and manage the greenhouse's internal environment, including:

- **Temperature Sensors:** Ensure the greenhouse remains within optimal growing temperatures.
- **Humidity Sensors:** Monitor moisture levels to prevent plant diseases and stress.
- **Light Sensors:** Measure light intensity and duration, crucial for photosynthesis.

5. Ventilation System: Necessary for regulating temperature and air quality inside the greenhouse, components include:

- **Roof Vents:** Allow hot air to escape, facilitating natural convection.
- **Side Vents or Louvers:** Enable cross-ventilation, bringing in fresh air.

6. Shade Systems: Though diffuse materials naturally reduce direct sunlight, additional shading equipment might be used during peak sun hours, including:

- **External Shade Cloths:** Deployed above the greenhouse covering.
- **Internal Shade Screens:** Used inside for temperature and light control.

7. Energy Systems: To ensure sustainability and efficiency, some greenhouses incorporate:

- **Solar Panels:** Generate renewable energy to power greenhouse operations.
- **Geothermal Heating:** Utilizes the earth's stable

temperature for heating or cooling.

8. Control Systems: Centralized or computerized systems that integrate sensors and actuators to automate the greenhouse climate, including

- **Environmental Control Units:** Manage temperature, humidity, and ventilation automatically.
- **Lighting Controls:** For supplemental lighting, ensuring plants receive the optimal light spectrum and intensity.

Findings

The study's findings indicate that diffuse covering materials, such as polycarbonate sheets, diffuse glass, and EVA films, significantly improve light distribution within greenhouses. This leads to uniform plant growth, enhanced photosynthesis, and increased crop yields. Diffuse glass, despite its higher cost, showed the best performance in light diffusion and yield improvement, suggesting its suitability for high-value crops.

These results have important implications for greenhouse technology, emphasizing the need for careful selection of covering materials based on crop requirements, economic considerations, and environmental factors. The use of diffuse coverings can lead to more sustainable agricultural practices by reducing the need for artificial lighting, lowering energy consumption, and improving water use efficiency.

Future research should focus on the long-term durability of these materials, their cost-effectiveness in various climates, and the integration with other advanced greenhouse technologies. The advancement in diffuse covering materials underscores the potential for material engineering to enhance greenhouse productivity and sustainability significantly.

Conclusion

The study on the "Technology of Diffuse Covering Materials for Greenhouses" has demonstrated the significant benefits these materials offer in enhancing the greenhouse growing environment. By improving the distribution of sunlight, diffuse covering materials contribute to more uniform and efficient plant growth, ultimately leading to increased crop yields and quality. Among the materials tested, diffuse glass emerged as the superior option for maximizing light diffusion, although its higher cost may necessitate a careful cost-benefit analysis for growers.

This research underscores the critical role of material technology in advancing sustainable greenhouse agriculture. The findings not only highlight the importance of selecting appropriate covering materials for optimizing plant growth conditions but also point towards the potential for reducing energy consumption and enhancing the overall environmental sustainability of greenhouse operations.

Looking forward, the continued innovation and development of new diffuse covering materials and technologies promise to further refine and improve greenhouse agriculture. As the demand for food production increases alongside the need for environmental sustainability, the advancements in greenhouse technology, as evidenced by this study, will play a pivotal role in shaping the future of agriculture.

In conclusion, the integration of diffuse covering materials into greenhouse design represents a significant step forward in the quest for more productive and sustainable agricultural

practices. Future research and development in this area will undoubtedly continue to unlock new potentials for enhancing crop production in controlled environments.

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