G-LIGHT: GREEN HOUSE MAGIC LIGHT AS AN INNOVATIVE PEST CONTROL SYSTEM FOR HORTICULTURAL CROPS SUPPORTING SDGS 2045

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Abstract
Indonesia is an agrarian country in which roughly 80% of the population works in agriculture, and horticulture is a key sector supporting national food security. Horticultural production, however, frequently faces yield losses from pest and disease attacks, including insects, nematodes, rodents, bacteria, viruses, and fungi, which reduce both crop quality and farmers' income. This study aims to design and describe G-Light, a futuristic innovation for pest control in horticultural plants, and to explain its advantages and benefits within a greenhouse farming context. Rather than relying on descriptive literature review alone, this study adopts a research and development (R&D) approach grounded in Design Science Research Methodology (DSRM), covering the problem-identification, objective-definition, design-and-development, and demonstration stages of building a technological artifact. Secondary data were collected through documentation study and internet searching, and analyzed descriptively through data reduction, data display, and conclusion drawing, complemented by a SWOT analysis of the proposed system. The results show that G-Light, which combines red and blue light spectra with a solar-powered irrigation and humidity-sensing system, is conceptually effective in improving plant growth conditions while suppressing pest populations inside a greenhouse without relying on chemical pesticides. The design further outlines a phased implementation roadmap, from prototype testing to pilot projects and broader adoption. G-Light is positioned as a environmentally friendly innovation that can enhance horticultural productivity and offers a practical reference for government bodies, non-governmental organizations, and communities seeking sustainable pest-management solutions aligned with the SDGs 2045 agenda
Keywords: G-Light; Horticulture; Pest Control; SDGs 2045; Sustainable Agriculture

1. Introduction

Food security is a multidimensional concept. The Food and Agriculture Organization (FAO) defines food security as a condition in which the whole population has physical, social, and economic access to stable, safe, and adequate food to sustain a better quality of life. Food security is realized when the food commodities a population requires can be fulfilled stably, accessed easily, and utilized optimally.

Indonesia is an agrarian country in which approximately 80% of the population earns its livelihood from agriculture and resides in rural areas. Horticulture is therefore a staple commodity that must be reliably supplied to sustain food security, and as the population continues to grow, horticultural production must be continuously developed and intensified. In practice, however, farmers face persistent challenges from pest and disease attacks on horticultural crops. Pests and diseases in horticultural plants are a major agricultural problem that can significantly reduce crop yields. Pests such as insects, nematodes, and rodents frequently cause physical damage to plants, lowering both the quality and quantity of harvests, while diseases caused by bacteria, viruses, and fungi can spread rapidly, causing wilting, leaf spots, and root rot. Pest attacks can damage leaves, fruit, and stems, reducing yields by 50%

or more under severe infestation, and ineffective pest management further raises production costs as farmers spend more on pesticides and labor. These impacts are felt not only by farmers but also by consumers, through rising food prices and declining product quality.

Indonesia's rapidly growing population, projected to exceed 300 million by 2050, places substantial pressure on the agricultural sector to meet food demand, while shifting consumption patterns toward healthier, fresher food continue to drive horticultural production, with commodities such as chili, tomato, and shallot showing annual production growth exceeding 5%. To address these food-security needs, the government and related stakeholders continue developing innovative agricultural technologies and practices, including improved crop varieties, efficient irrigation techniques, and organic farming, alongside greater investment in the horticulture sector.

Building on this background, the authors propose a Green House-based innovation titled G-Light: Green House Magic Light, an innovative pest-control system for horticultural crops intended to support the SDGs 2045 agenda. The central advantage of G-Light lies in its capacity to suppress pest and disease pressure on horticultural plants through a light-based mechanism rather than chemical pesticides. Although prior studies have examined greenhouse technology, LED-light effects on plant growth, and integrated pest-management practices separately, there have been limited studies that integrate solar-powered lighting, humidity sensing, and irrigation control within a single greenhouse system explicitly framed around dual red-blue light spectra for combined growth stimulation and pest suppression. Therefore, this study intends to design and describe the working principle of G-Light as a pest-control system for horticultural crops and to identify the advantages and challenges of its implementation, so as to contribute both to the scientific literature and to practical guidance for government bodies, non-governmental organizations, and the wider community.

2. Literature Review

This section reviews the conceptual foundations underpinning G-Light: the greenhouse and light-spectrum technology it builds upon, the horticultural context it serves, and the global sustainability agenda it is intended to support.

2.1. Greenhouse and Light-Spectrum Technology

G-Light is a compound term combining "G" for Green House and "Light" for illumination; literally, it may be read as "Green House of Light." In this study, the term refers to the application of an innovative lighting arrangement, or a light-based method, for pest control and for enhancing plant productivity. A greenhouse itself is a structure in which plants are cultivated to protect them from extreme environmental conditions and from pests that hinder growth, and its presence is also intended to cultivate greater environmental awareness among growers.

Related engineering studies reinforce the feasibility of technology-assisted greenhouse cultivation: prior work has designed a smart indoor greenhouse IoT prototype to address lettuce cultivation challenges, demonstrating that sensor-integrated environmental control can be implemented at a small scale. Complementary research on red and blue LED light intensity found measurable effects on the growth and productivity of cayenne pepper (Capsicum frutescens L.) under indoor systems, providing direct empirical grounding for G-Light's dual red-blue lighting mechanism, where red light stimulates photosynthesis and carbohydrate production while blue light is understood to disrupt pest behavior and reproduction.

2.2. Horticulture and Pest-Management Practices

Horticulture derives from the Latin hortus (garden) and cultura (cultivation), and can be defined as the cultivation of plants in gardens or home yards. It encompasses potential commodities including fruits, vegetables, medicinal plants, and ornamental plants, and has been recognized as a distinct field since the 17th century, originating in Italy and Central Europe, separate from staple food crops, plantation crops, and industrial crops.

Contemporary studies on horticultural pest pressure illustrate the scale of the problem this study addresses: research on fruit-fly (Bactrocera sp.) infestation in horticultural commodities traded in regional markets documents the persistent risk pests pose to marketable yield, while studies on integrated pest management (IPM) technology in cabbage cultivation and on botanical pesticides as pest-control agents both point toward a broader shift away from chemical-intensive pest control and toward integrated, environmentally sound alternatives a shift that G-Light is explicitly designed to support. Complementary work on greenhouse-based learning media further shows that greenhouses can double as environmental-literacy (ecoliteracy) infrastructure, suggesting that G-Light may carry educational as well as productive value.

2.3. Sustainable Development Goals (SDGs) 2045

The Sustainable Development Goals (SDGs) are a set of global action plans established by the

United Nations to achieve a better and more sustainable life for all. SDGs 2045 is envisioned as a global development program intended to promote worldwide community welfare and environmental preservation across 17 core goals and 169 associated targets within an agreed timeframe, and is closely linked to sustainable development, the Millennium Development Goals (MDGs 2030), and Corporate Social Responsibility (CSR).

Broadly, SDGs 2045 builds on the priorities established under MDGs 2030, envisioning that the younger generation can play a substantial role in advancing the global economy while safeguarding natural resources and leveraging technology so as not to fall behind more advanced nations. Within this framing, an innovative pest-control system for horticultural crops such as G-Light can contribute meaningfully to food-security resilience as part of the broader effort to achieve the SDGs 2045 agenda.

2.4. Synthesis

Taken together, the literature indicates convergent support for three elements of the G-Light design: (1) greenhouse structures as a proven means of protecting horticultural crops from extreme conditions and pests; (2) red-blue LED light spectra as an empirically supported mechanism for simultaneously enhancing plant growth and suppressing pest behavior; and (3) an urgent, internationally recognized need for environmentally sustainable pest-management alternatives consistent with the SDGs agenda. G-Light is positioned at the intersection of these three strands, integrating solar-powered dual-spectrum lighting with irrigation and humidity sensing within a single, replicable greenhouse system.

3. Research Methods

3.1. Research Design:A Design Science Research (R&D) Approach

Because this study's central contribution is the conceptual design of a technological artifact intended to solve a practical pest-control problem, a purely descriptive literature-review design was judged insufficient to capture the design and development process involved. Instead, this study adopts a research and development (R&D) approach grounded in the Design Science Research Methodology (DSRM), a methodology widely used in engineering, information-systems, and applied-innovation research for building and evaluating purposeful technological artifacts. Relative to classical education-oriented R&D models such as Borg and Gall's ten-step model or the 4D model (Define, Design, Develop, Disseminate), DSRM was selected because it is explicitly artifact-centered and does not presuppose a full field-implementation and dissemination cycle, making it well suited to a preliminary, conceptual-design study such as this one, whose scope ends at the demonstration of a validated design rather than large-scale field deployment.

Following Peffers et al.'s DSRM framework, this study covers four of the six standard stages: (1) Problem Identification and Motivation, in which the pest-related constraints on horticultural production were identified from the literature and framed as the study's rationale; (2) Definition of the Objectives of a Solution, in which the desired capabilities of a light-based, chemical-free pest-control system were specified; (3) Design and Development, in which the G-Light artifact comprising a solar power unit, red and blue LED lighting, an irrigation subsystem, and a humidity-sensing subsystem was conceptually designed and rendered as a three-dimensional prototype model; and (4) Demonstration, in which the design was illustrated through prototype visualizations, a component-function table, and a SWOT-based feasibility analysis. The final two DSRM stages, Evaluation and Communication (i.e., empirical field testing and broad dissemination), fall outside the scope of the present study and are instead articulated as a phased implementation roadmap for future work.

3.2. Data and Data Sources

This study relies on secondary data, defined as data not obtained directly from primary field sources. Data were drawn from books, official websites, scientific journals, articles, and credible online news sources relevant to greenhouse technology, LED-light effects on plant physiology, integrated pest management, and the SDGs 2045 agenda.

3.3. Data Collection Techniques

Data were collected through two complementary techniques: (1) internet searching, used to gather information and data relevant to the topic under study from online sources, and (2) documentation study, an indirect data-collection technique drawing on references such as books, articles, journals, and prior theses relevant to greenhouse and pest-control technology.

3.4. Prototype Design and Development Procedure

The G-Light artifact was developed through an iterative design process: an initial concept sketch specifying the required subsystems (solar power, dual-spectrum LED lighting, irrigation, humidity sensing) was translated into a three-dimensional computer-aided design (CAD) model of the greenhouse structure; individual subsystems were then specified and mapped to their functional roles within the system; and the resulting design was reviewed against the study's solution objectives before being documented as the final conceptual prototype presented in the Results and Discussion section.

3.5. Data Analysis Techniques

Data were analyzed using a qualitative descriptive technique comprising three stages: (1) data reduction, the process of selecting, simplifying, and transforming raw data gathered from documentary and online sources; (2) data display, organizing the reduced data into matrices, diagrams, or tables to facilitate comprehension of the G-Light system's design and function; and (3) conclusion drawing, in which insights regarding the feasibility, advantages, and challenges of G-Light were synthesized. This descriptive analysis was complemented by a SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis, used specifically to evaluate the strategic feasibility of implementing G-Light in real-world horticultural settings.

4. Results and Discussion

4.1. Research Results

Green House Light (G-Light) is a lighting system specifically designed to enhance plant growth conditions inside a greenhouse. The technology utilizes a targeted light spectrum, primarily red and blue wavelengths, to influence the growth of horticultural plants while simultaneously suppressing pest populations.

The visible-light spectrum used within G-Light is summarized in Table 1. Blue light, in particular, exhibits properties directly relevant to pest control: its use within the G-Light system disrupts pest behavior and reproduction, thereby effectively reducing pest populations without dependence on chemical pesticides. Red light within this spectrum is known to stimulate photosynthesis, a key process in plant food production, thereby helping increase the carbohydrate output required for overall plant growth, including leaf development and flowering.

Table 1. Visible Light Spectrum Used in G-Light

Visible Light Spectrum Color	Wavelength (nm)
Red	625–740
Blue	435–520

Source: Adapted from physics reference data on the visible light spectrum.

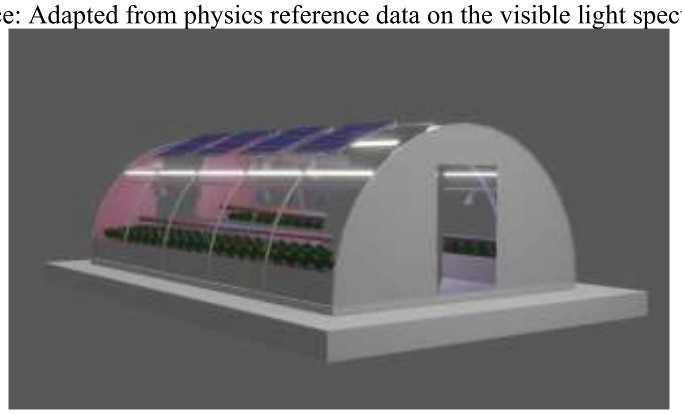

Figure 1. Full-Body Conceptual Design of the G-Light Greenhouse (Source: Authors, 2026)

Figure 2. Interior View of the G-Light Prototype Showing Lighting Arrangement (Source: Authors, 2026)

Table 2 lists representative horticultural crops suited for cultivation within the G-Light system, while Table 3 summarizes the core hardware components of G-Light and their respective functions.

Table 2. Horticultural Crops Suited for G-Light Cultivation

No.	Plant
1	Chili
2	Tomato
3	Strawberry
4	Lettuce
5	Spinach

Source: Processed by the authors, 2026.

Table 3. G-Light System Components and Functions

Component	Function
Solar Panel	Provides the electrical power supply to operate the system.
Red UV/LED Light	Increases carbohydrate production required for overall plant growth.
Blue UV/LED Light	Disrupts pest behavior and reproduction, reducing pest populations without chemical pesticides.
Irrigation System	Maintains soil moisture and plant health while preventing waterlogging.
Humidity Sensor	Monitors soil and air humidity levels, preventing damp conditions that attract pests such as fungi and aphids.

Source: Processed by the authors, 2026.

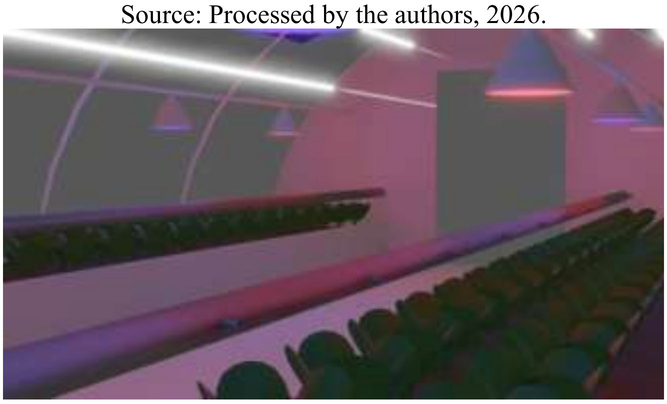

Figure 3. Horticulture Section Inside the G-Light Prototype (Source: Authors, 2026)

The proposed system's strategic feasibility was further assessed through a SWOT analysis (Figure 4). The analysis indicates that G-Light's principal strengths lie in reduced energy costs through solar power and reduced dependence on chemical pesticides, while its main weaknesses concern the initial infrastructure investment and the solar system's dependence on weather conditions. Opportunities include supportive sustainable-agriculture policy and the system's extensibility to other horticultural crops and geographic regions, whereas threats include economic uncertainty affecting farmers' investment capacity and climate variability affecting solar-panel efficiency.

Figure 4. SWOT Analysis of the G-Light Implementation Strategy (Source: Authors, 2026)

Successful implementation of G-Light requires coordinated support from multiple stakeholders, including central and regional government bodies and ministries providing funding, incentives, and regulatory support; community organizations supporting technology adoption and public education; academics contributing research and supervisory expertise; and structural/mechanical specialists together with material suppliers, investors, and funders ensuring the system is built to safe and appropriate standards.

Table 4 outlines the phased implementation strategy proposed for G-Light, spanning design and testing, pilot projects, phased implementation, marketing and partnership development, and a final success-projection and evaluation stage.

Table 4. Phased Implementation Strategy for G-Light

Stage	Description	Timeline
Design and Testing	Design, assembly, and testing of the G-Light prototype.	Juli-December 2026
Pilot Project	Selection of potential regions for implementation testing, in collaboration with government and other partners.	January-March 2027
Implementation	Phased rollout including permitting, socialization, and deployment of G-Light.	April-September 2028
Marketing and Partnership	Marketing to potential markets and partnership development with private-sector stakeholders.	December 2027-February 2028
Success Projection	Projection of success and evaluation of G-Light's effectiveness in addressing horticultural crop damage.	2029

Source: Processed by the authors, 2026.

4.2. Discussion

These results indicate that the conceptual design of G-Light directly answers this study's first research question regarding the working principle of the system: a solar-powered dual-spectrum lighting arrangement, combined with irrigation and humidity control, can plausibly regulate both plant-growth conditions and pest pressure within a single integrated greenhouse system. This finding is consistent with prior work on smart indoor greenhouse IoT prototypes and on red-blue LED light effects on chili productivity, which together support the biological plausibility of combining photosynthesis-stimulating red light with pest-disruptive blue light.

Regarding the second research question, on the advantages and challenges of implementing G-Light, the SWOT analysis suggests that the system's principal advantage is its potential to reduce reliance on chemical pesticides while lowering long-term energy costs through solar power, consistent with the broader shift toward integrated pest management and botanical or non-chemical pest-control alternatives documented in the literature. The identified weaknesses and threats high initial investment and weather-dependent solar performance indicate that successful adoption will likely depend on supportive financing mechanisms and regionally appropriate deployment, rather than on the technology alone.

As a conceptual, design-stage study, this research is limited in that G-Light's pest-control and yield-improvement claims have not yet been empirically validated through field trials; the reported benefits should therefore be interpreted as design-stage projections grounded in the cited light-spectrum and greenhouse literature, rather than as measured outcomes. Future research, corresponding to the Evaluation and Communication stages of the DSRM framework, should prioritize pilot-scale field implementation to empirically measure G-Light's effect on pest population reduction and horticultural yield across the phased timeline outlined in Table 4.

5. Conclusion

Green House Light (G-Light) is a lighting system specifically designed to enhance plant growth conditions inside a greenhouse. The technology utilizes a targeted light spectrum, primarily red and blue wavelengths, to influence horticultural plant growth and control pest populations within the greenhouse context. G-Light is thus expected not only to support plant growth inside a greenhouse but also to open new possibilities for pest management, offering a more sustainable and environmentally friendly approach to modern agriculture while contributing to the preservation of the environment for future generations. With appropriate and wide-scale application, G-Light can become a key solution in addressing global challenges related to food security and pest pressure. Government support for further research and development of G-Light through funding, training, and field-trial programs is recommended, together with incentives for farmers adopting this environmentally friendly technology as part of a broader, more sustainable approach to pest control that reduces dependence on chemical pesticides.

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