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Revamping polyhouse systems for sustainable agriculture: A comprehensive review

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Abstract
This review examines the process and outcomes associated with the revitalization of polyhouse systems and the evaluation of sustainable cropping models (SCM) in both controlled polyhouse environments and open-field conditions. The research is structured into three distinct phases: the restoration of a non-functional polyhouse, the assessment of sustainable cropping models in polyhouses and open fields, and the evaluation of their economic feasibility. The review provides a thorough analysis of infrastructural improvements, environmental control systems, and microclimate factors, emphasizing the benefits of polyhouse farming in enhancing crop productivity, resource efficiency, water management, and soil health.

Keywords: Polyhouse farming, sustainable cropping models (SCM), controlled environment agriculture, revamping polyhouses, infrastructure upgrades, irrigation system, water efficiency, microclimate control, crop productivity

Introduction

Polyhouse farming, which leverages controlled environmental conditions, is gaining increasing recognition for its potential to improve crop yields while mitigating the challenges posed by adverse weather. This paper provides a detailed review of efforts to restore non-functional polyhouses and develop sustainable cropping models (SCMs) that foster both environmental sustainability and economic viability. The study is organized into three phases: upgrading polyhouse infrastructure, assessing SCMs, and evaluating the economic feasibility of these systems.

Revamping the Non-Working Polyhouse and Developing a Sustainable Cropping Model

Existing Polyhouse Parameters

The polyhouse assessed in this study covers an area of 120 square meters, with a length of 15 meters, a width of 8 meters, and a height of 4.2 meters. These dimensions provide ample space for plant growth and effective air circulation. Previous research (Kumar *et al*., 2023) [2] suggests that polyhouses significantly improve crop productivity by creating an environment that mitigates adverse weather conditions. The initial investment of Rs 4,92,800 in the polyhouse is considered worthwhile, as polyhouses enable year-round cultivation of high-value crops, making them a promising agricultural investment (Singh and Sharma, 2020) [5].

Necessary Components for Polyhouse Revamping

Revamping the polyhouse required substantial upgrades, including improvements to the infrastructure, irrigation systems, and cooling mechanisms. Gupta *et al.* (2020) [3] underscore the importance of using high-quality materials like poly sheets to enhance polyhouse durability and efficiency. Incorporating modern irrigation technologies, such as drip irrigation and fogging, was vital for maintaining consistent moisture levels, while automated control systems helped monitor temperature and humidity (Sharma *et al*., 2022) [5].

Revamping Process

The polyhouse was extensively refurbished, with essential infrastructure components such as pipes, polyethylene sheets, and GI springs being reinstalled.

Singh *et al*. (2021) [7] emphasize that regular maintenance of polyhouse infrastructure is critical to preventing leaks and ensuring optimal light and temperature control. The reinstallation of the irrigation system, including drip systems and foggers, was necessary for efficient water distribution. Additionally, consistent electrical system maintenance was emphasized by Jain *et al*. (2021) [8] to ensure smooth operation of irrigation and cooling systems.

Costs Involved in Revamping

The revamping project amounted to Rs 1,65,060, with the largest expenditure dedicated to polyethylene sheets and the irrigation system. Gupta and Rani (2020) [3] note that, despite the significant upfront costs, investment in high-quality materials can lead to long-term savings and increased productivity, which justifies the initial expense.

Comparison between Revamped and Non-Revamped Polyhouse

The upgrades resulted in a 100% improvement in critical areas such as polyethene sheets, irrigation systems, and pest control measures. Jadav and Rosentrater (2017) [4] observed that such improvements in light and energy efficiency significantly enhance the microclimate of polyhouses, facilitating optimal crop growth.

Assessment of the Sustainable Cropping Model (SCM) of summer squash and Tomatoes in Polyhouse and Open Field

Evaluation of SCM: Production Parameters

The sustainable cropping model (SCM) in the polyhouse demonstrated notable improvements in water efficiency. Irrigation was required every six days in the polyhouse, compared to 24 days in the open field. The frequency of weeding was also reduced, with polyhouse crops requiring attention only once a month, while open-field crops needed weekly weeding. Singh Highlights that drip irrigation improves water use efficiency and supports healthy crop growth. Furthermore, Verma and Singh (2023) [9] emphasize the benefits of organic farming practices, which were implemented in both environments.

Temperature and Humidity Control

The polyhouse maintained a stable temperature range, which is crucial for consistent crop growth. In comparison to the open field, where temperatures fluctuated between 10 °C and 43 °C, the polyhouse ensured a more predictable environment with temperature stability between 13.0 °C and 25.0 °C. Verma and Singh (2023) [9] suggest that such controlled temperature conditions are optimal for plant growth.

Light and CO2 Levels

Light intensity in the polyhouse ranged from 5,928.3 Lux to 13,746.33 Lux, while the open field had significantly higher light levels. Bhat (2020) [10] notes that moderate light intensity, as observed in the polyhouse, is ideal for maximizing photosynthesis and crop productivity. Additionally, the polyhouse-maintained CO2 levels between 711.33 ppm and 858.87 ppm, which supported enhanced plant growth, aligning with the findings of Choudhury and Das (2023) [1].

Microclimate Parameter Differences

Statistical analysis revealed significant differences in temperature, humidity, light, and CO2 levels between the polyhouse and open field. The p-values ranging from 0.02 to 0.04 suggest that the polyhouse environment significantly outperforms the open field in terms of microclimate control. Mishra *et al*. (2021) [11] emphasize that microclimate optimization plays a key role in improving crop yields by providing a stable growing environment.

Economic Feasibility of Sustainable Cropping Models of tomatoes and summer squash

The financial analysis of the revamped polyhouse and SCM demonstrated that, while the initial investment is substantial, the resulting improvements in productivity, water efficiency, and labor requirements offer a favourable return on investment. The productivity of tomato was much better in the polyhouse as compared to open field cultivation. The same applied to summer squash as production of summer squash was also much higher in polyhouse rather than open field. These findings align with the economic benefits highlighted by Singh and Sharma (2020) [5], which support the economic viability of polyhouse farming despite significant upfront costs. It highlights the importance of polyhouse as the viable option for production of different crops.

Conclusion

The revamping of the polyhouse and implementation of sustainable cropping models resulted in significant improvements in crop productivity, environmental control, and economic feasibility. Enhanced infrastructure, irrigation systems, and microclimate management contributed to better resource utilization and higher yields. These results advocate for the broader adoption of polyhouse farming as a sustainable agricultural practice, particularly in regions facing weather uncertainties and water scarcity. Continued advancements in technology and cost-effectiveness will further cement polyhouse farming as a viable and sustainable agricultural method.

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