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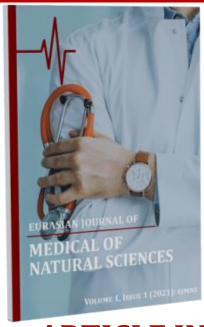

THE ROLE OF ARTIFICIAL LIGHTING TECHNOLOGIES IN PLANT GROWTH IN CLOSED ENVIRONMENTS

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ABSTRACT

Artificial lighting, Plant growth, Closed environments, LED technology, Fluorescent lamps, High-pressure sodium lamps, Photosynthesis, Light spectrum, Blue light, Red light, Far-red light, Phytochrome system, Plant development, Hormone production, Energy efficiency, Vertical farming, Microclonal propagation, Controlled environment agriculture, Light intensity, Spectral composition, Sustainable agriculture, Indoor farming, Plant physiology, Photoperiodism.

Introduction. Light is one of the most important environmental factors for plants, serving primarily as the main energy source in photosynthesis. In open fields, this need is fulfilled by sunlight. However, in closed environments such as greenhouses, laboratories, vertical farms, or underground systems, natural light is limited. Under such conditions, the use of artificial light sources is essential for the growth and development of plants.

In recent years, there have been significant advancements in artificial lighting technologies. Especially, the development of LED technology has brought revolutionary innovations in this field. LED lamps can produce specific wavelengths (i.e., certain spectral light) necessary for plants. This allows for more precise and efficient control of plant physiological processes.

Artificial Light Sources and Their Characteristics The main artificial lighting technologies used in closed environments include LED (Light Emitting Diode), fluorescent, and high-pressure sodium (HPS) lamps.

LED lamps represent the most modern technology. They are distinguished by high energy efficiency, long service life, low heat emission, and the ability to adjust the spectrum. In particular, LED lamps can produce only the required light spectra, enabling the regulation of light according to different growth stages of plants.

Fluorescent lamps have been used for many years in closed environments. They are mainly effective during the vegetative growth phase as they emit active radiation in the blue-green spectrum. However, compared to LEDs, their energy consumption is higher, their service life is shorter, and their light efficiency is lower.

High-pressure sodium lamps emit strong light mainly in the red-orange spectrum. They can be effective during flowering and fruiting stages. However, these lamps emit a lot of heat, which requires additional cooling systems.

1.LED (Light Emitting Diode) Lamps

Advantages:

a) Ability to precisely adjust the spectrum.

b) Low energy consumption (high energy efficiency).

c) Low heat emission – does not harm plants.

d) Long service life (up to 50,000 hours).

Applications:

e) Widely used in vertical farms, scientific laboratories, and microclonal propagation systems.

2.HPS (High Pressure Sodium) Lamps

Advantages:

a) High brightness level.

b) Strong radiation in the red-orange spectrum – stimulates flowering and fruiting.

Disadvantages:

c) High heat emission – requires ventilation.

d) Higher energy consumption.

3. Fluorescent Lamps

Advantages:

a) Low cost.

b) Operates in the blue-green spectrum – supports vegetative growth.

Disadvantages:

c) Relatively short service life.

d) Low light intensity.

The Effect of Artificial Lighting on Plant Development

The effect of light spectrum on plant growth and development is extensive. In particular, blue (400–500 nm) and red (600–700 nm) wavelengths are crucial for photosynthesis.

Blue light promotes dense and compact leaf formation, activates stomatal opening, and leads to short, strong-stemmed plants. This spectral range mainly stimulates vegetative growth.

Red light directly affects photosynthesis, especially the CO_2 fixation stage. It also regulates flowering, fruiting, and seed formation processes via phytochrome photoreceptors.

Far-red light (above 700 nm) regulates the photoperiodic response of plants. Through the phytochrome system, it helps plants "sense" day and night differences, determining flowering time and transition between vegetative and generative phases.

Practical Importance of Artificial Lighting in Closed Environments

There are several key advantages of artificial lighting in closed plant growing environments. Primarily, these systems can provide plants with continuous light for 24 hours, enabling faster growth, shorter vegetation periods, and stable year-round yields.

Additionally, artificial lighting systems allow complete control of the microclimate. Factors such as temperature, humidity, light intensity, and spectral composition can be artificially regulated. This enables the creation of customized conditions for each plant species.

Artificial lighting technologies are especially important in vertical farming. They enable multi-layer plant cultivation in small spaces, providing a vital solution for food security in large cities.

Moreover, these technologies allow plant cultivation in environments devoid of natural light, such as international space stations or deserts, enhancing their global significance.

Conclusion

Artificial lighting technologies play an invaluable role in plant cultivation in closed environments. They not only solve the problem of light deficiency but also provide the ability to fully control plant physiological and morphological processes. Especially with the widespread use of LED technology, factors like energy efficiency, spectral flexibility, and environmental safety are improving. In the future, artificial lighting systems will expand opportunities for intensive, efficient, and sustainable agricultural production.

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