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Indian Standard

IS 18807 : 2024

संरक्षित खेती के लिए कृत्रिम प्रकाश व्यवस्था — अपेक्षाएँ

Artificial Lighting System for Protected Cultivation — Requirements

ICS 65.020.99

भारतीय मानक ब्यूरो
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July 2024 **Price Group 7**

Agricultural Systems and Management Sectional Committee, FAD 22

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Agricultural Systems and Management Sectional Committee had been approved by the Food and Agriculture Division Council.

Light is one of the key requirements for plant growth. Artificial lighting is needed to grow plants in spaces where there is little or no natural light available or when the natural day length is artificially extended. Plants absorb light and use its energy to transform by the process called photosynthesis. Different particles present in plant absorbs different wavelengths of light spectrum. Chlorophylls absorb mainly red and blue light, phototropins absorb blue light, cryptochromes absorb UV-A (ultraviolet-A), blue, and green wavelengths; phytochromes red and far-red light UV-B, UV-A, (wavelengths between 280 nm to 380 nm) and far-red irradiation (wavelengths above 700 nm).

Photosynthesis, germination, time of flowering and plant morphology are light dependent activities. These actions are highly related to the surrounding light quality from which the plant perceives signals of its environment. These responses are mediated by wavelengths within and beyond the photosynthetically active radiation (PAR) area, including also UV and far-red irradiation. The ratios of blue to green ratio and red to far-red ratio determine how fast or slow the plant grows.

The standard has been developed in order to provide guidelines and standards for the use of artificial lighting for plant growth in various applications, such as controlled environment agriculture (CEA) and other related fields, in India. This standard will provide recommendations on requirements for lighting system, structures, safety, maintenance and also the basis for development of conformity assessment scheme in future in order to evaluate the artificial lighting system for protected cultivation.

The composition of the Committee responsible for the formulation of this standard is given in Annex A.

In reporting the result of a test made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'.

Indian Standard

ARTIFICIAL LIGHTING SYSTEM FOR PROTECTED CULTIVATION — REQUIREMENTS

1 SCOPE

This standard provides guidelines for the design, installation, operation, and maintenance of artificial lighting systems used in protected cultivation, including but not limited to indoor facilities, vertical farms, greenhouses, and other controlled environments.

2 REFERENCES

The standards given below contain provisions which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent edition of these standards:

IS No.	*Title*
IS 10322 (Part 1) : 2014	Luminaires: Part 1 General requirements and tests (*first revision*)
IS/IEC 60529 : 2001	Degrees of protection provided by enclosures (IP code)

3 DEFINITIONS

3.1 Artificial Lighting — Electric lighting systems used as a primary or supplemental light source to support plant growth and development in CEA.

3.2 Controlled Environment Agriculture (CEA) — Buildings or structures wherein electric lighting and other inputs (for example, air temperature, humidity, and water consumption) can be controlled to grow crops.

3.3 Daily Light Integral (DLI) — The total amount of light in the photosynthetically active radiation (PAR) range that is PPFD (3.10) received by a plant over a 24 h period, typically expressed in moles of light per square meter per day (mol/m²/day).

3.4 Edge Effect — Reduced light intensity at the periphery of the illuminated area of lighting fixtures, resulting from the fixture's internal design. Influenced by factors like reflector and lens configuration. This phenomenon requires optimizing internal elements to achieve uniform light distribution. Addressing edge effect is crucial in lighting design for consistent illumination and avoiding uneven lighting conditions.

3.5 Micromole — One millionth of a mole or 602 quadrillion.

3.6 Mole — A unit of measurement that is the amount of a pure substance containing the same number of chemical units (atoms, molecules, etc) as there are atoms in exactly 12 grams of carbon-12 (that is, 6.022 × 1 023).

3.7 Photoperiod — The period of time during which natural or artificial light is available to promote photosynthesis in plant life each day.

3.8 Photosynthesis Photon Flux (PPF) — PPF measures the total amount of photosynthetically active radiation (PAR) that is produced by a lighting system each second. The unit used to express PPF is micromoles per second (µmol/s). It is important to note that PPF does not tell how much of the measured light actually lands on the plants, but is an important metric if we want to calculate how efficient a lighting system is at creating PAR.

3.9 Photosynthetic Photon Efficacy (PPE) — A measure of how much PAR light is produced by an artificial lighting system from its input power. The metric unit used to measure PPE is micromoles/second/watt (PPF/watt), which can be simplified to umol/J. PPE measures a grow light's efficiency for converting electrical energy into PAR light. It is calculated through the following formula:

$$\text{Photosynthetic photon efficacy (PPE)} = \frac{\text{Photosynthentic photon flux (PPF)}}{\text{Amount of energy consumed}}$$

3.10 Photosynthetic Photon Flux Density (PPFD) — The number of photosynthetically activated photons that fall on the given surface area each second. Typically expressed in micromoles per square meter per second (µmol/m²/s).

3.11 Photosynthetically Active Radiation (PAR) — Radiation available for photosynthesis, known as photosynthetically active radiation (PAR), is light of wavelengths 400 nm to 700 nm and is the portion of the light spectrum utilised by plants for photosynthesis. In this context, the reason PAR is preferred over other lighting metrics such as luminous flux and illuminance is that these measures are based on human perception of brightness, which is strongly green biased and does not accurately describe the quantity of light usable for photosynthesis. PAR is a non-metric unit like kg, km, meter but PAR is type of light needed for plant growth. Quantum sensor is used to measure the light intensity in horticulture lighting. The distribution of PAR wavelengths is given in Fig. 1.

3.12 Wattage — Consumption of electricity to product desired PPFD.

4 LIGHTING TYPE BASED ON LIGHTING SOURCE

4.1 LED (Light-Emitting Diode) Lights

LEDs (light emitting diodes) are energy-efficient lighting solutions known for their adaptability and versatility. They offer precise control over wavelength and spectrum, making them highly suitable for horticultural applications across all stages of plant growth. The ability to tailor the light spectrum according to specific plant needs enhances efficiency and performance, making LEDs a preferred choice for diverse lighting purposes in the field of horticulture.

4.2 Compact Fluorescent Lights (CFL)

CFL bulbs are energy-efficient and emit a balanced spectrum of light suitable for plant growth. They are available in various colour temperatures, including cool white (for vegetative growth) and warm white (for flowering and fruiting stages). CFLs are often used for smaller indoor gardens or as supplementary lighting.

4.3 Metal Halide (MH) Lights

Metal halide lamps emit a bluish-white light that closely resembles natural sunlight. They are commonly used during the vegetative stage of plant growth due to their high output of blue spectrum light. MH lights produce intense light and require a ballast for operation.

4.4 High Pressure Sodium (HPS) Lights

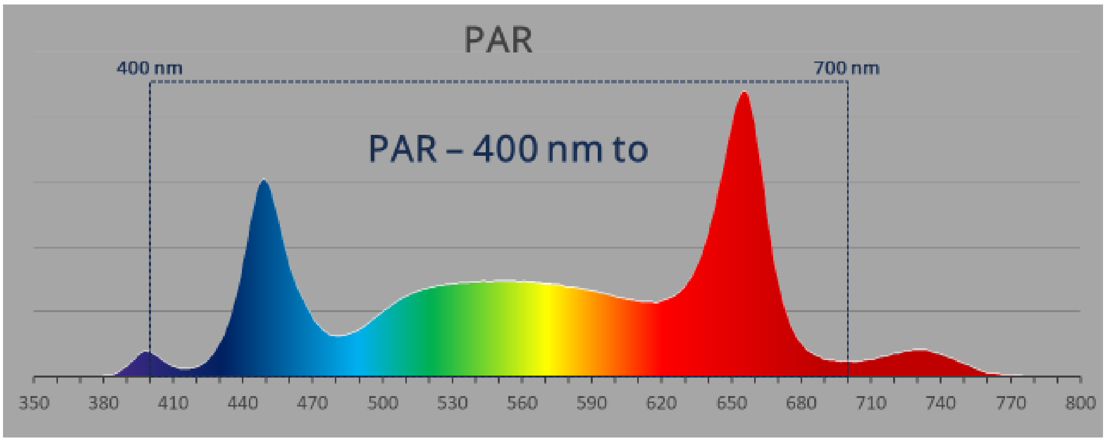
HPS lamps emit a strong yellow-orange light that is rich in the red and orange spectrum, making them suitable for the flowering and fruiting stages of plant growth. They are often used as the primary light source in commercial greenhouse operations.

4.5 Fluorescent Tube Lights

Fluorescent tubes, such as T5 and T8 bulbs, are commonly used for seed starting, cloning, or growing small, low-light plants. They are less intense compared to high-intensity discharge (HID) lights but offer a good balance of light spectrum for young or delicate plants.

4.6 Induction Lights

A type of energy-efficient lighting that uses electromagnetic fields to produce light. They are not as common as other options but have been used in some horticultural applications due to their long lifespan and low heat output.



NOTE — In general, plants grown under ultraviolet light have thick leaves and stems and short internodes. Plants grown under high blue irradiation have short internodes, high dry matter content and low leaf temperature (efficient transpiration). Plants grown under green light have long petioles internodes and high leaf temperature. High far-red irradiation causes premature flowering in many species, and elongation of stem and petioles.

FIG. 1 PHOTOSYNTHETICALLY ACTIVE RADIATION (PAR)

5 LIGHTING TYPE BASED ON APPLICATION

5.1 Sole-Source Lighting

This lighting type should be intended for applications where the lighting fixture is the primary source of optical radiation for inducing photobiological effects in crops. A figure depicting sole-source lighting is given in Fig. 2.

5.2 Supplemental Lighting

This lighting type should be used to supplement daylight or another product that is the primary light source. A figure depicting supplemental lighting is given in Fig. 3.

5.3 Photoperiodic Lighting

This is the delivery of low intensity light to create long day when day are short. As plants receive enough DLI from short day, the typical intensity delivered by photoperiodic lighting is 1 to 2 PPFD which is bright enough for plant to perceive. Primary objective of such lighting is to regulate flowering when plants are sensitive to day length. A figure depicting photo-periodic lighting is given in Fig. 4.

FIG. 2 SOLE SOURCE LIGHTING

FIG. 3 SUPPLEMNTAL LIGHTING

FIG. 4 PHOTOPERIODIC LIGHTING

6 LIGHTING TYPE BASED ON POSITION

6.1 Close Canopy Lighting

Close canopy light should be intended to be mounted with the emission area facing downward, toward the plant canopy. This lighting should be used when the gap between light and plant canopy is not more than 2 ft.

6.2 Top Lighting

Top light should be intended to be mounted with the emission area facing downward, toward the plant canopy. This lighting should be used when the gap between light and plant canopy is more than 2 ft.

6.3 Inter Lighting or Intra-canopy Lighting

This lighting type should be intended to be mounted within the plant canopy.

NOTE — Considering the additional lighting requirements, other supporting lighting options may be used. Other lighting option supports products that do not fit within the top lighting or intra-canopy lighting categories may be mentioned as “other (text)” [for example, “other (ground-mounted lighting)” or “other (side lighting)”].

7 IMPORTANT ARTIFICIAL LIGHTING PARAMETERS

7.1 Light Quality

Light quality refers to the spectral distribution of light, or the relative number of photons of blue, green, red, far-red, and other portions of the light spectrum emitted from a light source. The light quality effects growth, photosynthesis, leaf anatomy, and volatile isoprenoids of a monoterpene-emitting herbaceous species and an isoprene-emitting tree. Light quality is measured by a spectrometer. Different wavelength of light has different role in photosynthesis.

7.1.1 *Red Light* (*Wavelengths from* 600 nm *to* 700 nm)

Red light promotes flowering and fruiting in many plant species. It is often used during the reproductive stage to increase flower bud formation and improve fruit quality.

7.1.2 *Blue Light* (*Wavelengths from* 400 nm *to* 500 nm)

Blue light is crucial for vegetative growth, leaf expansion, and chlorophyll synthesis. It is often used during the vegetative stage to promote compact and bushy plant growth.

7.1.3 *Green Light* (*Wavelengths from* 500 nm *to* 600 nm)

Adding green light can help with canopy photosynthesis, because it penetrates further down into plant canopies, it can also be a signal to help boost biomass growth.

7.1.4 *Far-red Light* (*Wavelengths Around* 700 nm *to* 800 nm)

Far-red light influences plant elongation, stem growth, and flowering time. It can be used to control plant height and flowering initiation.

7.1.5 *UV* (*Ultraviolet*) *Light* (*Wavelengths Below* 400 nm)

UV light can induce plant defence mechanisms and affect the production of secondary metabolites, which typically provide flavours and aromas.

7.2 Light Intensity

This is usually defined as the energy hitting an area over some time period. So, in the case of a plant, a higher light intensity means more packets of light called 'photons' are hitting the leaves Light intensity can be measured by PAR meter and its unit is PPFD (µmol m-2 s-1). Also, DLI (mol m-2 s-1) is defined as the daily dose of the plant. Light intensity plays a crucial role in plant lighting as it directly influences plant growth, development, and overall health. Lighting intensity plays an important role in photosynthesis, growth and morphology, flowering and fruit production, nutrient intake and plant response.

7.3 Lighting Photoperiod

Photoperiod (3.7) refers to the duration of light and darkness that plants are exposed to, within a 24 h period. It plays a crucial role in regulating flowering induction, vegetative growth, dormancy, and various physiological processes in plants. Different plant species have specific photoperiodic responses, categorized as short-day plants (flowering induced by long nights), long-day plants (flowering induced by short nights), and day-neutral plants (flowering not significantly influenced by photoperiod).

7.4 Lighting Uniformity

Lighting uniformity in artificial lighting systems is essential for consistent plant growth, optimal light distribution, balanced photosynthesis, avoiding shadowing and hot spots, efficient resource utilization, achieving desired plant responses, improved control and monitoring, and enhanced harvest quality. It plays a critical role in maximizing productivity and ensuring successful cultivation in indoor and controlled environment settings. Lighting installation and system dimensions plays important role to provide uniform lighting.

8 LIGHTING RECOMMENDATIONS

8.1 Close Canopy Lighting

8.1.1 *Performance Parameters*

8.1.1.1 The life span of driver and fan of the lighting system shall be a minimum of 20 000 h.

8.1.1.2 The PPE of the system shall be 1.6 or more (umol/J).

8.1.1.3 The edge effect shall be less than 10 percent.

8.1.1.4 The spectrum distribution shall be from 400 nm to 750 nm.

8.1.1.5 The lighting system shall have a degree of protection rated as a minimum of IP 53 as per requirements mentioned under IS/IEC 60529.

NOTE — For Grass fodder application the lighting system must be of IP 65 as per requirements mentioned under IS/IEC 60529.

8.1.2 *Electrical Parameters*

8.1.2.1 The individual lights in the artificial lighting system shall pass electromagnetic interference (EMI) and when tested between 9 KHz to 30 MHz it shall read to performance.

NOTE — EMI represents unwanted electrical noise within the light. In controlled environment agriculture, where multiple lights are often clustered together, ensuring EMI compliance is crucial for safety. Therefore, EMI testing is deemed essential.

8.1.2.2 Wire size should be as per the current flow rating and wire material should be of rubber.

8.1.2.3 Other remaining electrical parameters should be as per IS 10322 (Part 1).

8.1.3 *Lighting Parameters*

DLI for microgreens shall be 6 mol/m²/d to 15 mol/m²/d, for vegetative growth (leafy greens/herbs) shall be 8 mol/m²/d to 17 mol/m²/d and for flowering crops shall be 15 mol/m²/d to 30 mol/m²/d.

8.1.4 *Photoperiod*

For a long day plant, the photoperiod shall be above 14 h of light during all stages of plant. However, for a short-day plant, the plant should get 12 h to 14 h of darkness during flowering stage.

8.1.5 *PPFD*

The PPFD for leafy greens shall be 100 µmol/m²/s to 300 µmol/m²/s, for microgreens it shall be 100 µmol/m²/s to 200 µmol/m²/s and for flowering and fruiting plants it shall be 150 µmol/m²/s to 350 µmol/m²/s.

8.1.6 *Design and Installation Parameters*

8.1.6.1 Gap between two layers (stacks) of plantation for leafy greens shall be 15″ to 18″; out of which the NFT height is 2″ and grow bar height is 1″. So effective height shall be 12″ to 15″ (*see* Fig. 5).

8.1.6.2 For micro greens/grass fodder gap between two layers shall be between 8″ to 10″ (effective height of 6″ to 8″).

8.1.7 *Number of Layers* (*Stacking*)

Minimum number of layers shall be of 2 and the maximum number of layers depends up on height. Fig. 6 depicts a typical multilayer structure of artificial lighting system.

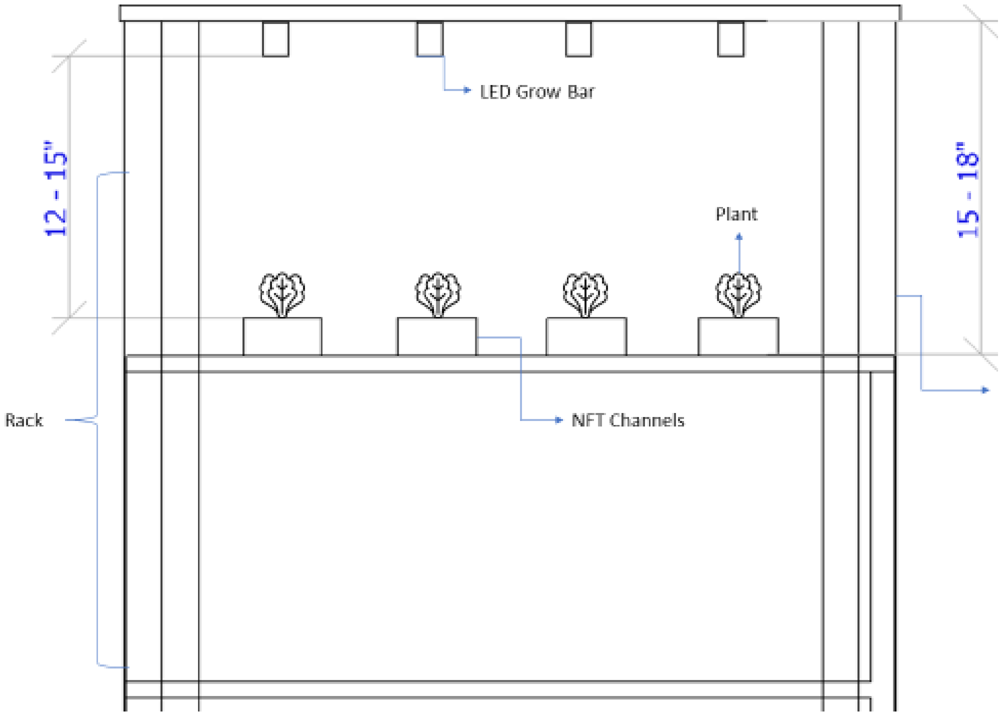


FIG. 5 DESIGN OF PLANTATION UNDER ARTIFICIAL LIGHTING

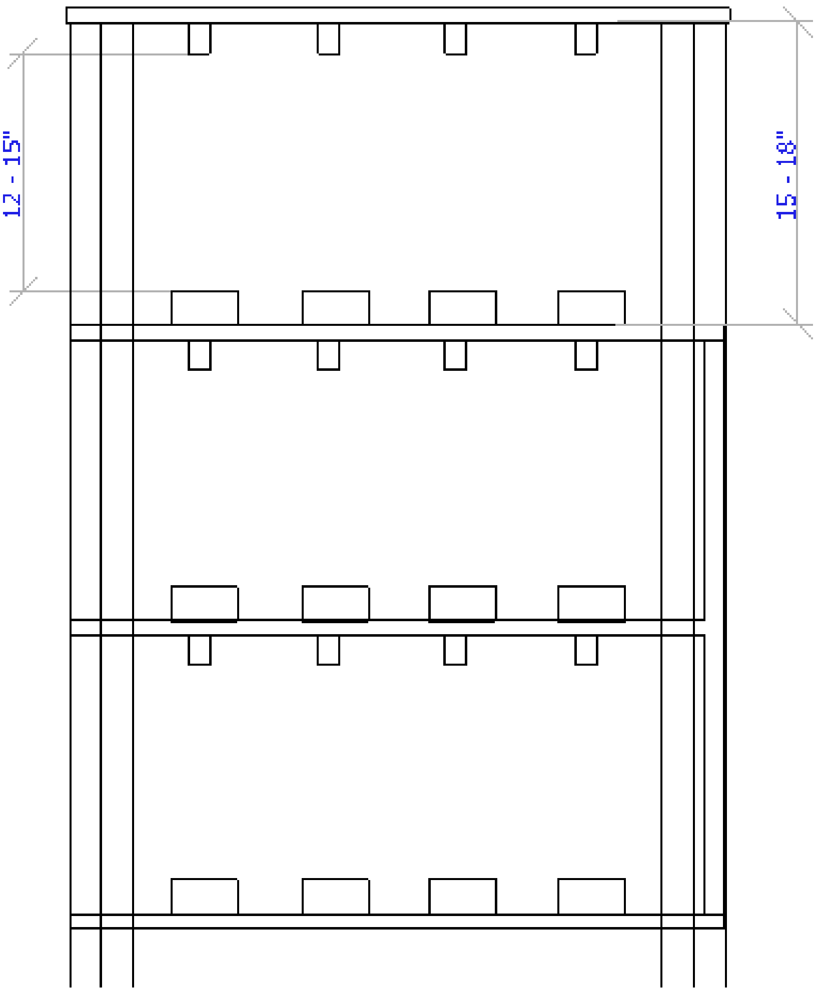


FIG. 6 DESIGN OF MULTILAYER PLANTATION UNDER ARTIFICIAL LIGHTING

8.1.8 *Other Parameters*

8.1.8.1 The Lighting system should be of maximum rated temperature of 50 °C and minimum rated temperature of - 10 °C.

8.1.8.2 Unless specified, all other lighting parameters shall be as per IS 10322 (Part 1).

8.1.9 *Lighting Control*

The lighting system should have a dimming capability, which shall be mentioned in product specification sheet along with its dimming range and dimming control method.

8.2 Top Canopy Lighting

8.2.1 *Performance Parameters*

8.2.1.1 The PPE of the system shall be 1.9 or more (umol/J).

8.2.1.2 The lighting system shall have a degree of protection rated as a minimum of IP 65 as per requirements mentioned under IS/IEC 60529.

8.2.1.3 The requirements for other performance parameters shall be as given in **8.1.1.1**, **8.1.1.3** and **8.1.1.4**.

8.2.2 *Electrical Parameters*

The requirements electrical parameters shall be as per **8.1.2**.

8.2.3 *Lighting Parameters*

The requirements lighting parameters shall be as per **8.1.3**.

8.2.4 *Photoperiod*

The requirements photoperiod shall be as per **8.1.4**.

8.2.5 *PPFD*

The requirements PPFD shall be as per **8.1.5**.

8.2.6 *Installation Parameters*

The gap between light and plants shall be a minimum of 2 ft and maximum of 6 ft (*see* Fig. 7).

8.2.7 *Other Parameters*

The requirements for other parameters shall be as given in **8.1.8**.

8.3 Supplemental Lighting

Supplementary lighting is an artificial lighting source used in green house to get sufficient light quantity and quality. Supplemental lighting extends the photoperiodic hours in a day.

NOTE — In order to calculate the required supplemental lighting for plant growth, supplemental light = plant lighting requirement (DLI) — Available DLI from sunlight where, plant lighting requirement is the typical DLI values mentioned under **8.1.3** and available DLI depends on location and diffusion percent of polyhouse structure. To check available DLI at your location one can refer https://nsrdb.nrel.gov or https://solcast.com/solar-radiation-map/india.

9 GENERAL REQUIREMENTS

9.1 Energy Efficiency

Lighting systems shall be designed to maximize energy efficiency, taking into account lighting efficacy (photon per watt), power factor, and utilization of advanced lighting technologies.

9.2 Safety

Lighting systems shall comply with relevant electrical safety standards and regulations to ensure the safety of personnel, crops, and the environment. Unless specified, all other safety parameters shall be as per IS 10322 (Part 1).

9.3 Maintenance

Adequate provisions shall be made for regular maintenance and inspection of lighting systems to ensure optimal performance and longevity. Unless specified, all other safety parameter shall be as per IS 10322 (Part 1).

9.4 Documentation

Detailed documentation, including lighting system specifications, installation plans, electrical diagrams and maintenance records shall be maintained for reference and compliance purposes.

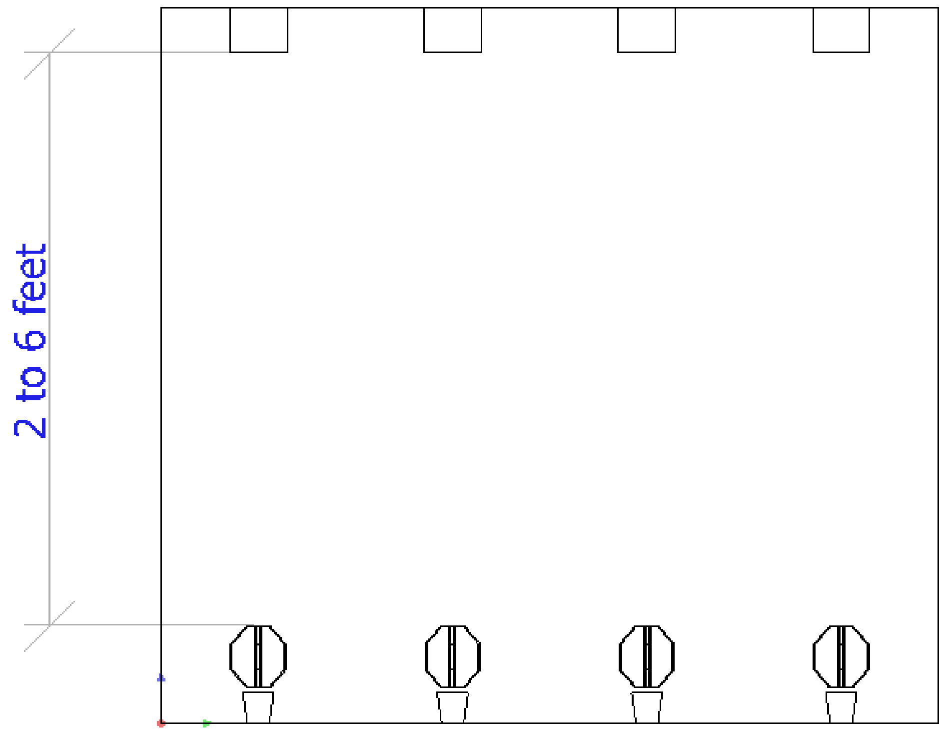


FIG. 7 DESIGN OF PLANTATION UNDER TOP CANOPY ARTIFICIAL LIGHTING

ANNEX A

(*Foreword*)

COMMITTEE COMPOSITION

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Organization	*Representative(s)*
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Amendments Issued Since Publication

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