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MANAGEMENT OF LIGHT, TEMPERATURE, HUMIDITY AND CARBON DI OXIDE (CO_2) IN PROTECTED STRUCTURE

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Abstract

Environments which can be modified allow any crops for their growth and development for any season. In this article elaborately discussed about the different environmental factors which directly affect the plant life cycle in a protected structure. Light is an important growth factor and artificial sources are incandescent lamps (ILs), fluorescent lamps (FLs), high-pressure mercury lamps (HPMLs), high-pressure sodium lamps (HPSLs), and metal-halide lamps (MHLs) have been used for lighting in controlled environment. Active and passive heating as well as cooling systems are used to control the temperature. The use of cooling systems (e.g., pad-and-fan or fog) during the warmer summer months increases the greenhouse air humidity. About 70% of relative humidity should be maintained in the greenhouse for better plant growth. Different CO_2 enrichment method such as Decomposition of straw, combustion, Liquid CO_2 and Solid C_{O2} are used in controlled environment. Proper management of these components offers distinct advantage for quality, productivity and favorable market price to the growers. It increases their income in off– season as compared to normal season.

Introduction

Protected cultivation is the modification of the natural environment to achieve optimum plant growth. Modifications can be made to both the aerial and root environments to increase crop yields, extend the growing season and permit plant growth during periods of the year not commonly used to grow open field crops. One of the benefits of growing crops in a greenhouse is the ability to control all aspects of the production environment. Horticulture today forms an integral part of food, nutritional and economic security. Using protected structure virus free cultivation of tomato, chilli, sweet pepper, cucumber and other vegetables mainly during rainy season easily be grown.

Management of light intensity

Light is one of the key growth factor for plant growth and development. In a controlled environment light is maintained as per requirement of a particular crop grown.

Source of light

a. Sunlight : Sunlight is the only source of light in open field cultivation. Electrical light, in addition to sunlight, can be an additional source of light in greenhouse cultivation.

b. Artificial source of light : According to Gupta and Agarwal (2017) various conventional light sources are incandescent lamps (ILs), fluorescent lamps (FLs), high-pressure mercury lamps (HPMLs), high-pressure sodium lamps (HPSLs), and metal-halide lamps (MHLs) have been used for lighting in greenhouses and controlled environmental condition.

1. Incandescent : Incandescent lamps are available in the range of 40-500 W at 115 and 230 V and have only 7% light energy conversion ratio since lamps provide excessive heat to obtain particular light level.

2. Fluorescent lights : Fluorescent lamps provide a linear light source rather than a point source and have a specific light output of 40-60 lumen/Watt. These lamps give cool white light for plant growth. They convert about 20% electrical energy into light energy and are available up to 2.5 m length. These lamps are most commonly used in crops like cucumber, tomato and capsicum grown inside greenhouse.

3. High intensity discharge lamps : High intensity discharge (HID) lamps are compact and are less affected by temperature changes. They required less maintenance and easily convert electrical energy into photosynthetically active radiation very efficiently. The different types of HID lamps are: a) sodium lamps (High and low pressure) b) Mercury lamps c) Metal halide

a. Sodium lamps (High and low pressure) : Two types sodium lamps are categorized such as high and low pressure lamps. High pressure lamps responsible for yellow-orange part of its spectrum whereas low pressure lamps for yellow light. These lamps light are produced by the passage of an electric current at high temperature through vaporized sodium under pressure. High pressure sodium lamps are 33% more durable compared to low pressure sodium lamps. It converts 25% of electrical energy into visible light.

b. Mercury lamps : The light is produced by the passage of an electric current through a gas or vapours medium under high pressure.They are available in the sizes of 400W and 1000 W and produce a bluish-white light with a little red part of spectrum.

c. Metal Halide : Metal halide lamps releases about 50% more light than mercury lamps which can convert 20 % of electrical energy into visible light. Light they produced mostly in blue-violet part of the spectrum, which makes their common combination with high pressure sodium lamps (yellow-orange part of spectrum). These lamps are available in varying sizes up to 2000W with short span of light; lose their output fast and costly.

Gupta and Agarwal (2017) stated that these light sources have certain drawbacks such as fixed spectral output, high-power requirement, emission of heat, and short life span. Invention of light-emitting diodes (LEDs) has changed the scenario for artificial lighting in controlled environmental condition. Low power consumption and long life span of LED lamps become a ideal choice for plant lighting in small- and large-scale operations.

Table 1. Light Source Comparisons

Light Source	Efficacy* (lumens/watt)*	Lifetime (hours)
Incandescent		
Traditional	10–17	750-2,500
Energy-Saving Halogen	12–22	1,000–4,000
Fluorescent		
Straight Tube	30–100	700–24,000
Compact	50–70	10,000
Circline	40–50	12,000
High-Intensity Discharge		
Metal Halide	70–115	5,000–20,000

High-Pressure Sodium	50–140	16,000–24,000
Light-Emitting Diodes		
Cool White LEDs	60–92	25,000–50,000
Warm White LEDs	27–54	25,000–50,000

Source: Gupta and Agarwal (2017)

Controlling light by shading

Intensity of radiations can be managed by providing shades (partial or full) at the controlled environment. It can be done by painting the glazed surfaces of the greenhouse or by putting a net or shading screen under the greenhouse frame. Recently use of UV stabilized plastic covering material is being pracrticed.

Management of temperature

Solar radiation is the primary source of the latent heat in a green house which largely affect the others growth factors (Sehi and Sharma, 2007). All crop required a certain temperature range for their proper growth and development, beyond this range plants give abnormality. The majority of plants grown in greenhouses are warm-season species, adapted to average temperatures in the range 17-27°C, with approximate lower and upper limits of 10 and 35 °C respectively. Bailey (1991) recorded that the management system of temperature through fan and pad cooling system influenced by the plant canopy, green house cover and external shading. In temperate climates, heating and ventilation enable the temperature to be controlled throughout the year, while at lower latitudes; the daytime temperature is too high for ventilation to provide sufficient cooling during the summer. Positive cooling is then required to achieve suitable temperatures.

Heating

It is often necessary to heat the greenhouse or tunnel to prevent damage to the crop from extreme cold and to obtain optimum growth. Passive heating can be done by heat retention and actively by extra heating inside.

a. Passive heating

Cover of plastic film : By covering the ground with plastic film and using tunnels and greenhouses a part of the day's radiant energy can be retained thus, a form of passive heating. Generally materials of these plastic are made from low density poly ethylene (LDPE) and ethylene-vinyl acetate (EVA) or ethylene-butyl acrylate (EBA) co-polymers (Espi *et al.*, 2006)

Heat conservation in water : A part of the suns radiant energy can also be retained cheaply by placing black plastic film bags filled with water between the rows of crops on top of the soil. This water warms up during the day and gradually gives off its warmth to the greenhouse air.

Heat retaining plastic film : A better way to retain extra warmth is by choosing a more expensive plastic film for the greenhouse cover. EVA-film is most frequently used for this purpose.

Energy screens : Energy screens have also been used for a few decades to reduce heat loss during night

Reed mats : The rolling out (reed) mats over the greenhouse cover for the night.

Hotbed manure : By loading fresh straw-rich manure and covering it with layer of soil, microbial fermentation producing heat. Thus the temperature of the upper surface of the soil rises and this promotes root development and growth of the crop.

b. Active heating

Active heating of a greenhouse is also something that has been practiced for ages.

Air heating : In its cheapest form, this is done by placing one or more heaters in the greenhouse and channelling the waste fumes upwards and out of the greenhouse via gradually ascending piping. In this way you can try to get a certain degree of distribution of the heat output.

Water heating : Warm water will then be pumped around the greenhouse through pipes to give off heat evenly.

How to heat : The heating concepts that can be used for heating greenhouse are heaters, solar radiation, fuels or conventional methods and heat pumps

A. Heaters : Heat supplied by the heaters to the greenhouse must be at the same rate at which it is lost by conduction, infiltration and radiation. Load calculations in high temporal resolution facilitates the optimization of the conditions in the greenhouse installations, resulting optimal vegetable or other plants productions, as well as the optimal heating/cooling units selection especially solar and/or other RES systems (Ikonomopoulos *et al*, 2016).

B. Solar radiation : Solar radiation is the main source of heat generation. They can be effectively used for obtaining heat in the greenhouse.

C. Conventional methods

Burning of fuels : In this method, conventional fuels such as cow dung cake, coal and wood etc. are used for heat generation. The burning of fuels produces CO_2, which helps in maintaining the CO_2 level inside the greenhouse.

Use of isothermal mass : Water is usually used as isothermal mass for absorbing and releasing heat inside the greenhouse as in water storage passive and active system.

Use of heat pumps: Heat pumps are also used to increase the efficiency of the heating system for circulating hot water through heat exchangers installed inside the greenhouse.

Greenhouse cooling

In the tropics, due to high irradiance in summer, the plant temperature in greenhouse can exceed the air temperature by 5-15°C.

Methods of greenhouse cooling

Natural and forced ventilation are the two methods used in greenhouse for cooling. When ventilation is not sufficient for cooling of the greenhouse, additional arrangements are made. In both force as well as natural ventilated green houses, proper ventilation has been shown to increase the uniformity of the air temperature and relative humidity in the controlled environment (Willits, 2003).

a. Natural ventilation : Natural ventilation is induced by natural means i.e. wind forces and thermal buoyancy. It is frequently a part of ventilation schedule for greenhouses and is an intermediate step before fans or other means of cooling are activated. In moderate climates, natural ventilation may be capable of providing the majority of ventilation during a year. Natural ventilation can be very vigorous and may be designed to provide as much or more airflow than a mechanical ventilation design using conventional techniques. Increase the area of roof windows lead to improve the ventilation rate, and subsequently reduces temperature of the air, floor surface, and decreases the soil heat flux value (Abdel-Ghani and Kozai, 2006).

b. Forced ventilation: Forced ventilation by fans is the most effective way to ventilate a greenhouse help to keep green house temperature at ambient level and used when needed (Ganguly and Ghosh, 2011). The fans must exhaust air from the greenhouse; the exhaust fans improve the temperature distribution and the distance between two fans should not exceed 8-10 m. and ventilation fans should developed a capacity of about 30 Pa static pressure (3 mm on a water gauge) (Sapounas *et al*, 2008). Sapounas *et al*. (2008) described that a space of at least 1.5 times the fan diameter should be left between the fan discharge and the nearest obstruction and the inlet opening on the opposite side of a fan should be at least 1.25 times the fan area. The velocity of the incoming air must not be too high. In the plant area it should not exceed 0.5 m/s.

Management of humidity : Humidity in the atmosphere has its own responsibility for most of the metabolic and photosynthesis activities of the plants. A relative humidity between 30-70 per cent is ideal for most of the plant growth. In case of tomato optimum humidity for proper growth and development in ranges about 50-70 percent and tomato pollination is significantly increase when it maintained around 60 percent relative humidity (Harel *et al*., 2014). Values below 60 per cent may occur during ventilation in arid climates, or when plants are young with small leaves, this can cause water stress. Very high relative humidity (exceeds 95% for long periods) enhance pathogenic organisms making the plant susceptible to fungal diseases. In controlled chamber, relative humidity between 55 to 65% and temperature of 20 to 25°C is maintained. During the day, humidity can usually be reduced using mechanical ventilation. However, at night, unless the greenhouse is heated, the internal and external temperatures may be similar; if the external humidity is high, reducing the greenhouse humidity is not easy. The use of cooling systems (e.g., pad-and-fan or fog) during the warmer summer months increases the greenhouse air humidity. Under normal conditions, about 70% of relative humidity should be maintained in the greenhouse for better plant growth.

Management of carbon dioxide (CO_2)

The amount of CO_2 present in the plant environment affects the plant growth because it is essential for photosynthesis.

CO_2 enrichment methods

Vermeulen (2014) described different source of CO_2 enrichment methods which is summarized as bellow :

Decomposition of straw : Straw is placed in the field, enriched with optimum fertilizers and wetter. CO_2 is released during decomposition and the disadvantage of this method is it takes more time and the amount of CO_2 released cannot be controlled.

Combustion : CO_2 and H_2O are produced when a hydrocarbon is burnt in the presence of sufficient oxygen and release CO_2. Fuel should have less than 0.02% of sulphur by weight to avoid toxic effects of sulphur oxides.

Liquid CO_2 : Under high pressure CO_2 is remained in liquid form which emit gas at low pressure can be regulated with the help of a set of regulating valves.

Solid C_{O2} : C_{O2} under high pressure and low temperature remained in solid form and is known as dry ice. This dry ice can be used for the enrichment of CO2 in greenhouse**.**

Conclusion

Adoption of horticulture, both by small and marginal farmers has increased in commercial aspect. Making available of different horticultural crops as well as their product throughout the year is a challenge to the farmers. By creating artificial environment any crops can be grown at any time through installation of protected structure and its proper management. In this article elaborately discussed about the different environmental factors which may helpful for proper management of a artificial environment required in a protected structure. Protected cultivation of vegetables offers distinct advantage of quality, productivity and favorable market price to the growers throughout the year. It increases their income in off– season as compared to normal season.

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